Lower Columbia River Reed Canarygrass Macroinvertebrate and Macrodetritus Production Study

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Abstract

Reed Canarygrass (*Phalaris arundinacea*) is a dominant invasive plant species found in emergent wetland habitats throughout the lower Columbia River. Previous observations in the lower river indicate that the presence of *P. arundinacea* may decrease plant species diversity and affect aquatic food web function; however, the extent of these ecological effects is unknown. Juvenile salmon utilize emergent wetland habitats for foraging and refuge during outmigration. Macroinvertebrates, such as Diptera (Chironomidae, in particular) are a preferred prey item for juvenile Chinook salmon, thus production and availability of these prey in wetland habitats are crucial for rearing success. Since invasive plant species often cause declines in the diversity, quantity, and quality of wetland plant communities, as well as reduced macrodetrital contribution and quality, *P. arundinacea* may also affect insect assemblages in the lower Columbia River.

We conducted a study that examined the production, supply, and retention of macrodetritus derived from *P. arundinacea* and native plant communities in order to better understand the relative contribution of these two vegetation types to salmon prey resources. We sampled environmental controlling factors (substrate, elevation, and hydrology), macroinvertebrates (community, biomass, and abundance), vegetation structure (composition and cover), macroinvertebrate food resources (macrodetritus quantity, quality, and decay rates), and macrodetritus production (seasonal vegetation biomass change) in emergent wetland habitats dominated by either *P. arundinacea* or native Lyngbye's sedge (*Carex lyngbyei*). Sampling sites were established between river kilometer (rkm) 52 and 72 on the lower Columbia River, a section of the river where the inundation regimes are similar and the elevation ranges of both *P. arundinacea* and *C. lyngbyei* overlap. Vegetation assemblage, detritus, and invertebrate sampling were conducted in April, May, and June 2014; vegetation biomass was collected in August 2014 during summer peak growth and in February 2015 after winter die-off. To capture a range of life stages utilizing habitats in the study area, macroinvertebrates were sampled using three trap types: fall out traps, emergence traps, and benthic cores.

Vegetative biomass was similar between sites dominated by the two plant types; however, average winter biomass was greater for *P. arundinacea* than *C. lyngbyei*, as *P. arundinacea* had a greater standing stock during the winter ($p = 0.037$). This indicates a greater quantity of detrital material available during the peak salmonid migration period from *C. lyngbyei* than from *P. arundinacea* given the differences in timing of transition from standing stock to detritus and subsequent slower decomposition of the *P. arundinacea* detritus. Additionally, the quality of detritus from *C. lyngbyei* was higher ($p < 0.001$) as measured by the carbon to nitrogen ratio (C:N) in large and small mesh litter bags and therefore more beneficial to salmon prey taxa.

Macroinvertebrate community composition from fallout and emergence traps showed seasonal shifts and increases in abundance throughout the sampling period. When all invertebrate taxa were considered, the abundance and biomass of fallout and emergence traps were similar between habitats dominated by *P. arundinacea* and habitats dominated by *C. lyngbyei*; however,

the abundance of all taxa combined was greater in benthic cores collected from *C. lyngbyei* sites than *P. arundinacea* sites ($p = 0.003$). For salmon prey taxa, the abundance of Diptera and Chironomidae from fallout traps and benthic cores, as well as the biomass from fallout traps was greater in *C. lyngbyei* habitats than in *P. arundinacea* habitats ($p < 0.05$). Emergent Diptera and Chironomidae abundance and biomass, however, were generally similar between the two vegetation types.

The overall macroinvertebrate community assemblage and diversity did not appear to be negatively affected by habitats dominated by *P. arundinacea*; however, we found that salmon prey taxa (Diptera and Chironomidae) were reduced in *P. arundinacea* sites. The greater density and biomass of salmon prey taxa from fallout traps and benthic cores in *C. lyngbyei* habitats indicates a possible negative effect of *P. arundinacea* on the production of these taxa. Other studies have shown detritivores (such as larval chironomids) to be less affected by invasive plants when compared to other feeding types, and also considering the degree of detrital mixing observed in the study area, the difference between the two vegetation types may not be of a magnitude that affects juvenile Chinook salmon trophic function. Additional study focusing on prey production in different vegetation types with a comparison to juvenile salmon insect consumption would contribute to reducing uncertainty.

Acknowledgments

This study could not have been completed without the help of our partners. We are grateful to the Northwest Power and Conservation Council and the Bonneville Power Administration for funding this study through the Columbia Basin Fish and Wildlife Program. Members of the Expert Regional Technical Group (ERTG) provided comments on a draft study design and early version of this report. This effort could not have been completed without the help of numerous field and laboratory assistants. We would like to thank Shon Zimmerman, Nichole Sather, Eric Fischer, Alexandra Simpson, and Allison Cutting from PNNL; Bob Oxborrow, Elizabeth Armbrust, Clifton Heermann, Alyssa Suzumura, Sasha Troiano, and Michael Caputo from University of Washington; and Keith Marcoe from the Estuary Partnership. We also thank the land owners and managers who have allowed us to conduct research on lands they manage, including Ian Sinks (Columbia Land Trust) and Paul Meyers (Lewis and Clark USFWS National Wildlife Refuge). Finally, the Estuary Partnership Science Work Group provided valuable input throughout the process and peer review on drafts of this report. The Science Work Group is composed of over 60 members, and is integral in ensuring the Estuary Partnership represents the best available science.

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1 Introduction

The Columbia River historically produced one of the largest Pacific salmon runs in the world (Netboy 1980). However, dike construction and land conversion for agricultural development have caused large-scale losses of floodplain and side channel habitats and the construction of the hydropower system has altered the hydrological regime, contributing to reductions in the quality and availability of salmon habitat (Kukulka and Jay 2003). As juvenile salmonids migrate downstream, they depend on an array of habitats types as areas for foraging, refuge and growth (Bottom et al. 2005; Fresh et al. 2005; Roegner et al. 2008). Emergent wetlands in the lower river are particularly productive and have been shown to provide abundant prey sources and valuable rearing habitat for young salmon (Sagar et al. 2015). These habitats in the lower Columbia River are especially important for ocean-type stocks that require longer rearing periods in estuarine and tidal freshwater habitats prior to ocean entry.

Over 5000 non-native plants have been introduced into the United States, and hundreds of these plant species are well established in natural ecosystems, including a number of aggressively invasive species (Tallamy 2004). Invasive plants can form dense, monotypic stands and displace native plant assemblages, altering plant community structure and composition (e.g., Lavergne and Molofsky 2004, Schooler et al. 2009, Claeson et al. 2014). Study of how the replacement of native plants by aggressive, non-native species affects the native diversity and biological integrity of animal consumers that rely on these plant communities is imperative for protecting aquatic ecosystem quality (e.g., Tallamy 2004, McMillan and Cook 2008, Schooler et al. 2009, Spyreas et al. 2010, Claeson et al. 2014).

Reed canarygrass (*Phalaris arudinacea*) is one of the most dominant invasive plant species in emergent marsh habitats in the lower Columbia River and has been documented in undisturbed and created marshes across the region (Sagar et al. 2013; 2015). In general, habitats that contain reed canarygrass have lower native plant species diversity and its establishment displaced native plant species on river islands and banks (Christy and Putera 1993). Long-term ecological trends data collected from the lower Columbia River recognized that reed canarygrass invasions decrease plant species diversity and have the potential to affect food web dynamics in the lower Columbia River ecosystem (Sagar et al. 2013); although, the extent of the effects of reed canarygrass is currently unknown.

Emergent marshes provide complex habitat for salmon and salmon prey, as well as a source of macrodetritus to downstream areas. Macrodetritus historically formed the base of the salmonid food web in the lower Columbia River; however, broad scale losses have reduced the detrital inputs from vascular plants into the system (Sherwood et al. 1990). Recent monitoring results indicate that reed canarygrass provides, on average, a lower detrital contribution than native plant species such as *Carex lyngbyei*, likely due in part to reed canarygrass having a lower rate of decay and thus a larger amount of standing stock remaining between years (Hanson et al. 2015).

Wetland vegetation benefits macroinvertebrate communities by providing structure (used for refuge from predation and environmental stressors) and food sources in the form of living vegetation and detritus. A preferred food source for juvenile Chinook salmon in the lower Columbia River is the insect order Diptera, primarily from the family Chironomidae (Sagar et al. 2013, 2015). Although stomach content analyses have shown that juvenile Chinook salmon will also consume other prey items such as crustaceans (amphipods, cladocerans, copepods), Hemiptera (true bugs), and Trichoptera (caddisflies), Diptera are often consumed at higher rates than expected given their availability in the habitats sampled (Sagar et al. 2015). Feeding habitats of macroinvertebrate taxa vary considerably, many are collector-gatherers or scavengers, consuming detritus or fine particulate organic matter and microbial organisms associated with that material.

If reed canarygrass invasions result in declines in the diversity, quantity, or quality of host or forage plants, declines in arthropod consumers and their predators would also be expected to occur (Spyreas et al. 2010). Most herbivorous insects are specialized on a few plant hosts; therefore, declines in plant species diversity may translate into declines of herbivorous insect diversity, and consequently predatory and parasitic arthropod diversity (Knops et al. 1999, Schooler et al. 2009). In addition, many non-native plant species are unpalatable to native insect assemblages, and therefore the energy sequestered by these plants may not be as readily available to herbivorous insects or their predators (Tallamy 2004). In a review of 56 studies of the impacts of plant invasions on local arthropod communities, van Hengstrum et al. (2014) found that plant invasions significantly reduced local arthropod abundance and taxonomic richness compared to un-invaded habitats. Thus, studying the insect assemblages and the production, supply, and retention of macrodetritus derived from reed canarygrass and native plant communities would allow for a comparison of the relative contributions of these two vegetation types to salmon prey resources.

In 2012, the Expert Regional Technical Group (ERTG) created a list of key scientific uncertainties associated with salmon recovery and habitat restoration in the lower Columbia River (ERTG 2012). Addressing these uncertainties is intended to fill knowledge gaps and assist with implementation of Columbia Estuary Ecosystem Restoration Program (CEERP) efforts by ensuring that well-informed decisions are made using the best available science. One uncertainty outlined by the ERTG asks, “what are the effects of aquatic invasive species on food webs supporting juvenile salmon?” in relation to riparian habitats. To address this key uncertainty, we investigated the following two questions:

1) Are there differences in the macroinvertebrate community structure (particularly salmon prey) or the availability of important juvenile salmon prey taxa in vegetation patches dominated by invasive *P. arundinacea* and native wetland species *C. lyngbyei*?
2) Does the supply, quality or retention of macrodetritus differ between patches of *P. arundinacea* and *C. lyngbyei*?

In order to answer these two questions, we sampled environmental controlling factors (substrate, elevation, and hydrology), macroinvertebrates (community, biomass, and abundance), vegetation structure (composition and cover), macroinvertebrate food resources (macrodetritus quantity, quality, and decay rates), and macrodetritus production (seasonal vegetation biomass change) in emergent wetland habitats dominated by either *P. arundinacea* or *C. lyngbyei*. To assist in answering our research questions, we developed four hypotheses:

1) Macroinvertebrate (i.e., important salmon prey) density, biomass, and community are reduced in patches of *P. arundinacea* compared to patches of *C. lyngbyei*.
2) The quantity and quality of available macrodetritus decreases with increasing percent cover of *P. arundinacea*.
3) Decomposition rates and detritus quality of *P. arundinacea* are lower than that of *C. lyngbyei* during the juvenile salmon migration period.
4) Macrodetritus production is lower in areas of higher percent cover of *P. arundinacea*.

This study was funded by the Northwest Power and Conservation Council/Bonneville Power Administration (NPCC/BPA). Study results are intended to support data collected by the Ecosystem Monitoring Program (implemented by the Lower Columbia Estuary Partnership) and inform regional habitat restoration efforts and action effectiveness monitoring. Data will also provide information towards implementation of the 2008 Federal Columbia River Power System (FCRPS) Biological Opinion (BiOp; NMFS 2008) and will help address the BPA Columbia Estuary Ecosystem Restoration Program (CEERP) goal of improving habitat opportunity, capacity and realized function for aquatic organisms, specifically salmonids.

2 Methods

2.1 Study Area and Site Selection

Tidally influenced emergent wetlands in the lower Columbia River have been shown to provide important benefits to rearing juvenile salmon (Sagar et al. 2013; 2015), thus our site selection methods targeted such habitats. In the Columbia River, reaches upstream of rkm 89 are river-dominated rather than tidally-dominated (Jay et al. 2015) and freshet flows inundate emergent wetlands for prolonged periods of time in these upper reaches of the estuary, thus potentially precluding access for sampling during the peak salmonid outmigration period. Salinity in the lower reaches of the estuary (below rkm 50) can preclude *P. arundinacea* growth and may contain different macroinvertebrate communities than freshwater dominated reaches. Therefore, in order to be able to effectively sample and compare habitats containing *P. arundinacea* and native vegetation, the study area was located between river kilometer (rkm) 50 and 89 on the lower Columbia River and all sampling was conducted in tidal emergent wetland habitats.

Six study sites dominated by *P. arundinacea* and six sites dominated by *C. lyngbyei* were selected within the study area (Figure 1, Table 1). We chose to sample patches of *C. lyngbyei* (rather than a mix of native species) for comparison with patches of *P. arundinacea* because it overlaps in elevation with *P. arundinacea* (1.4 – 1.8 m relative to the Columbia River Datum [CRD]), is similar in above ground structure, and co-occurs with *P. arundinacea* within the study area. Study sites were selected based on a set of predefined criteria prior to commencement of sampling, as follows:

- to minimize variability as a result of geomorphology and local hydrology, all sites were located at elevations between 1.4 and 1.8 m (CRD)
- sites were covered by a relatively homogeneous patch of the target vegetation (50% or greater cover of the target species)
- sites were greater than 5 m from other habitat features (i.e., open water, large patches of dominant non-target vegetation) to reduce landscape-scale influences.

To delineate each study site, we visually determined the location of a "patch" of target vegetation. We then measured five meters from the edges of the patch to create a rectangular study site within the center of the patch. The corners and center of each site were marked with PVC poles. Site boundaries and elevation were marked and recorded using a handheld global positioning system (GPS) unit in conjunction with real time kinematic (RTK) equipment. All sites were tidal freshwater, with a tidal range of approximately 1.8 to 2.1 m over the sampling period.

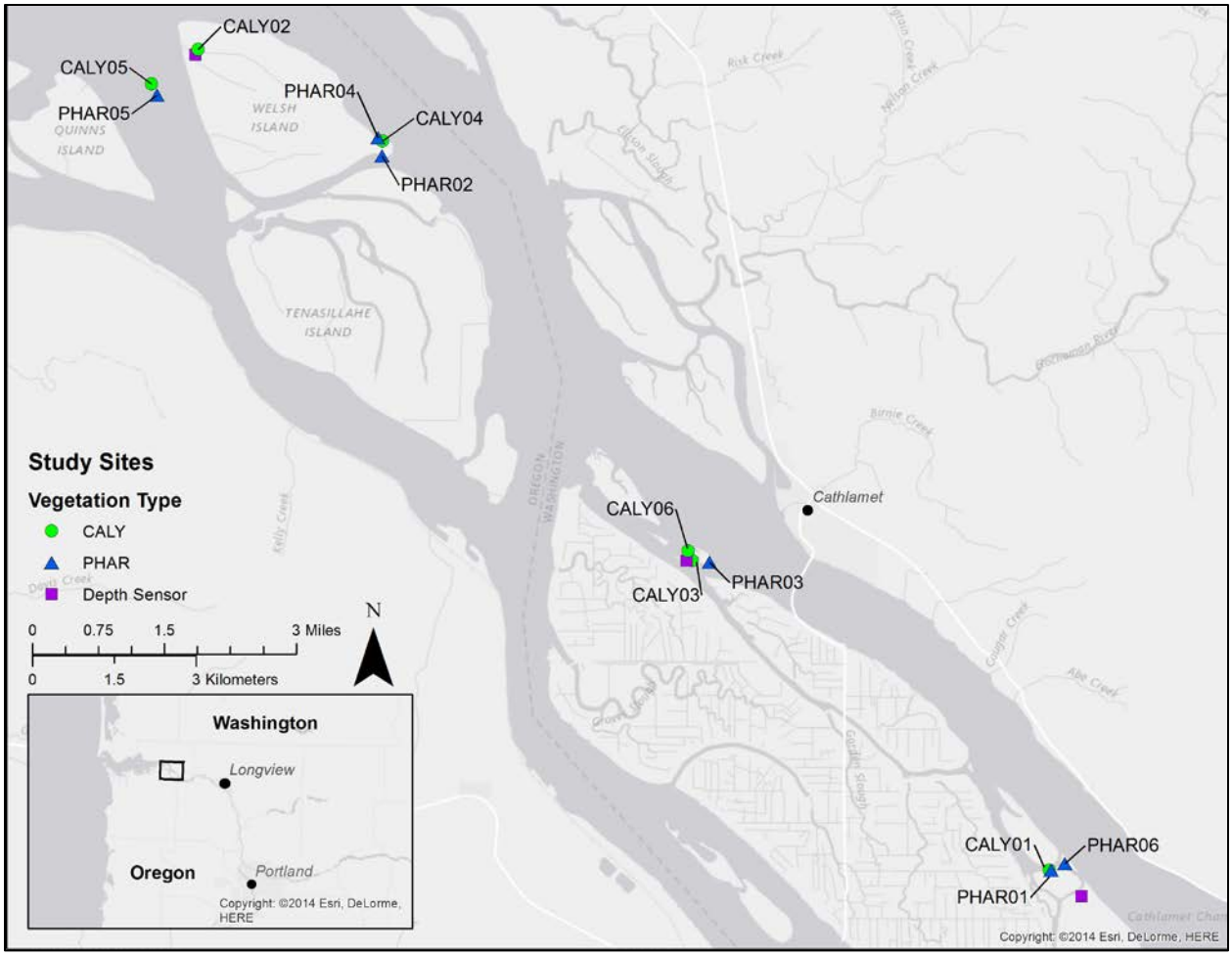


Figure 1. Map depicting study area and location of study sites and depth sensors.

Table 1. Description of sampling sites. Sites are listed in order from downstream to upstream. Orientation refers to the position of the site in relation to the nearest main channel. Elevation is presented in CRD (Columbia River Datum).

Study Site	Vegetation Type	River Kilometer (rkm)	Coordinates	Average Elevation (m, CRD)	Dimensions (m)
CALY5	Lyngbye's sedge	52	46.252° N -123.491° W	1.45	20 x 2
PHAR5	Reed canarygrass	52	46.250° N -123.490° W	1.61	28 x 2
CALY2	Lyngbye's sedge	53	46.256° N -123.483° W	1.76	14 x 4
PHAR4	Reed canarygrass	56	46.246° N -123.454° W	1.73	13 x 2
CALY4	Lyngbye's sedge	56	46.245° N -123.453° W	1.60	12 x 4
PHAR2	Reed canarygrass	56	46.243° N -123.453° W	1.60	13 x 4
CALY6	Lyngbye's sedge	62	46.199° N -123.404° W	1.46	15.5 x 5
CALY3	Lyngbye's sedge	62	46.197° N -123.402° W	1.41	14.5 x 4
PHAR3	Reed canarygrass	62	46.197° N -123.399° W	1.67	25 x 2
CALY1	Lyngbye's sedge	72	46.162° N -123.343° W	1.56	14 x 4
PHAR1	Reed canarygrass	72	46.162° N -123.343° W	1.74	11 x 4
PHAR6	Reed canarygrass	72	46.163° N -123.341° W	1.49	10 x 2

2.2 Sampling Design

Field sampling occurred once per month in April, May, and June 2014, corresponding with the typical peak juvenile Chinook salmon outmigration period through the lower river (Carter et al. 2009), which allowed for an estimate of the resources expected to be produced and available to juvenile salmon and prey during this time period. Macroinvertebrate and vegetation data were sampled concurrently in order to establish any existing relationships between macroinvertebrate and plant communities (i.e., vegetation cover were measured at the same locations as macroinvertebrate sampling). Several subsamples of both macroinvertebrate (traps/benthic cores) and vegetation (quadrats along transect) data were collected within each site because density and percent plant cover could vary and affect the macroinvertebrate community. Subsampling locations were established by running a transect tape along the length of each site from a randomly selected starting point on an established baseline. Several sites were only two meters wide, in which case the transect tape was placed down the center of the site. Four or five subsampling locations were established along the designated transect, beginning at the random start point and spaced at equal intervals intended to maximize coverage of the length of the site

and enhance sample independence. Subsamples within a site were located at least 1 m from the edge of the site to reduce edge effects. Subsamples were averaged or totaled to estimate density or biomass and to also explore the small scale spatial variability within a site. In addition, plant cover was characterized for the entire patch of vegetation around each site to account for any potential landscape effects.

2.3 Environmental Controlling Factors

2.3.1 Substrate

2.3.1.1 *Field Collection*

One sediment sample was collected from each site in May 2014. Each sample was homogenized from four cores (3 centimeter [cm] by 10 cm deep) collected at an evenly spaced interval along the longitudinal gradient of the site. The sites were thought to have relatively homogeneous sediment characteristics, however subsamples were collected to ensure the sample was representative of the entire site.

2.3.1.2 *Lab Processing and Analysis*

Samples were processed for grain size and total organic carbon (TOC) by Analytical Laboratory Services, Kelso, Washington. The samples were analyzed according to the ASTM Standard Method D4129Mz for TOC by high temperature oxidation and by coulometric detection. The grain size was analyzed according to methods developed by the Puget Sound Estuary Program for measuring sediment variables (PSEP 1986). The grain size was reported according to the breakdown in Table 2. Percent fines were calculated to include silt and clay, which was used along with TOC as explanatory variables for data analysis of vegetation and macroinvertebrate community differences.

Table 2. Sediment grain type and Phi size used for measuring sediment variables.

Description	Phi Size
Gravel (>2.00 mm)	<-1 Ø
Sand, Very Coarse (1.00 mm to 2.00 mm)	-1 to 0 Ø
Sand, Coarse (0.500 mm to 1.00 mm)	0 to 1 Ø
Sand, Medium (0.250 mm to 0.500 mm)	1 to 2 Ø
Sand, Fine (0.125 mm to 0.250 mm)	2 to 3 Ø
Sand, Very Fine (0.0625 mm to 0.125 mm)	3 to 4 Ø
Silt (0.0039 mm to 0.0625 mm)	4 to 8 Ø
Clay (< 0.0039 mm)	> 8 Ø

2.3.2 Elevation

2.3.2.1 *Field Collection*

Elevations were measured during the initial site selection process to ensure the study sites were within the predetermined elevation range of 1.4 m to 1.8 m, CRD at which both *P. arundinacea* and *C. lyngbyei* coexisted (Sagar et al. 2013). The four corners of each site were surveyed. In addition, elevations were measured during the landscape scale analysis at each point where vegetation cover was estimated. The three water depth sensors were also surveyed.

Surveys were conducted with a Trimble RTKGPS with survey-grade accuracy. All surveying was referenced to the North American Vertical Datum of 1988 (NAVD88); horizontal position was referenced to North American Datum of 1983 (NAD83). Local surveyed benchmarks were used to provide the vertical control to which the surveys were referenced.

2.3.2.2 *Data Processing and Analysis*

Trimble Geomatics Office (TGO) software was used to process the data. Each survey was imported and reviewed. Benchmark information was entered into TGO and rover antenna heights were corrected for disc sink (measured at each survey point to the nearest centimeter) at each point. The survey was then recomputed within TGO and exported in a geographic information system (GIS) shapefile format. Surveys were visually checked within TGO and GIS software for validity. Elevations were then converted from NAVD88 to CRD based on conversions developed by the US Army Corps of Engineers (USACE; unpublished data). Using the CRD alleviates elevation differences associated with the increasing elevation of the river bed in the landward direction and allows for direct elevation comparisons between sites in the lower Columbia River. All elevations in this report are referenced to CRD unless noted otherwise.

The elevation data collected at the sites were used in the following analyses:

- Elevation of the depth sensors allowed the water depth data to be converted to water surface elevation data.
- Elevation of the four corners of each site was averaged and used to calculate the inundation frequencies for the site.
- Elevation data from the vegetation quadrats allowed for the determination of the elevation ranges of each species encountered in the landscape scale vegetation survey.

2.3.3 Hydrology and Inundation

2.3.3.1 *Field Collection*

Pressure transducers (HOBO U-20 Water Level Data Loggers, Onset Computer Corporation) were deployed at three locations spanning the study area: Welch Island, Ryan Island, and Whites

Island (just upstream from Jackson Island) to log in situ water level (Figure 1). Measurements were recorded every hour between April 2014 and February 2015.

2.3.3.2 *Data Processing and Analysis*

Pressure data was downloaded from each sensor and converted to water depth using Hoboware (Onset Computer Corporation) and local atmospheric data collected near Cathlamet, Washington for the same time period. Water depths were converted to water surface elevation (WSE) using the surveyed elevations of the depth sensors. Inundation of the study sites within each site was calculated by determining the percent of hourly WSE records that were above the average elevation of the sites. The calculations were done for each of the two week periods prior to the three macroinvertebrate sampling periods in April, May, and June.

2.4 Vegetation Species Assemblage

The cover and composition of the vegetation community was surveyed at two scales during the study. Site scale surveys were conducted within the study sites, while a landscape scale analysis was completed in order to quantify the vegetation cover of the surrounding wetland.

2.4.1 Site Scale

Vegetation cover and species assemblage was collected in April, May, and June within each study site at the same locations as the macroinvertebrate sampling. A 1 m^2 quadrat was placed on both sides of the randomly selected sample location along the linear transect. All plant species were identified using taxonomic references (Cooke 1997; Dennis and Halse 2008; Hamel et al., 2001; Hitchcock and Cronquist 1973; Pojar and MacKinnon 2004) and the cover of each species was estimated to the closest five percent increment. Species deemed to have less than five percent cover were given a cover value of one percent. A total of eight to ten quadrats were sampled at each site, depending on the size of the site. The quadrats were averaged to give a representative estimate of the species assemblage and cover at each site.

2.4.2 Landscape Scale

Vegetation cover and species assemblage were collected in August, the peak of vegetation production, for the wetland area surrounding each site. An area at least 20 m on each side of the study sites was surveyed where possible; at some sites the proximity to woody vegetation or open water limited the sampling to a distance less than 20 m. A systematic sampling method was employed where a baseline transect was placed with sampling transects located at equal intervals perpendicular to the baseline. Starting points for the placement for each transect and quadrat placement were randomly chosen. All plant species were identified and the cover of each species was estimated to the closest five percent increment within a 1 m^2 quadrat at each sample location. Species deemed to have less than five percent cover were given a cover value of one percent. The quadrats were averaged to give a representative estimate of the species assemblage and cover at each site.

Vegetation communities within the landscape scale area were delineated by walking the boundaries between dominant vegetation communities with a differential GPS (Trimble GeoXH). The GPS data was downloaded to a geographic information system (GIS) where the vegetation communities were mapped. Metrics such as location of the site along the Columbia River by river kilometer (rkm), patch size, wetland area, and distance to the main stem of the Columbia River were calculated using GIS. See Appendix B for vegetation maps of each site and location of site scale and landscape scale sampling.

2.5 Vegetation Production and Decomposition

Three methods were employed to evaluate differences between the two types of vegetation communities in primary productivity, decomposition rates, and macrodetritus production. We collected above ground biomass in August at the peak of standing stock as an estimate of primary productivity for the year. Samples were collected again in February after winter die-off; the difference in the standing stock between summer peak and winter die-off provided an estimate of the amount of macrodetritus produced annually. Litter bags containing leaf and stem material from each plant type were deployed to determine decomposition rates and the quality of the litter during the decomposition process. Finally, sediment samples were taken at each site to determine the amount and quality of detritus present within the vegetation communities during the sampling period.

2.5.1 Above Ground Vegetation Biomass

2.5.1.1 *Field Collection*

Samples for above ground biomass were collected in August at the estimated peak of standing stock and again in February during the lowest standing stock, prior to the initiation of new growth. Four samples were collected from each site by clipping all rooted above ground vegetation within a 0.1 m^2 quadrat. Each sample was separated in the field by whether the vegetation was alive or dead and by three categories: 1) *P. arundinacea*, 2) *C. lyngbyei*, and 3) other species.

2.5.1.2 *Lab Processing and Analysis*

Samples were rinsed with freshwater over a 0.5 mm sieve to remove mud but preserve fine organic material. Samples were dried in a 105°C oven for a minimum of four days or until the samples no longer changed weight after multiple returns to the oven.

The four above ground biomass samples (collected from each of the 12 sites) were pooled and averaged by vegetation type within each sample site. The primary vegetation types for each site were compared between summer and winter, with the live material in summer compared to the standing dead remaining in winter. This allowed for the calculation of 1) the summer peak

standing stock, 2) the winter standing stock remaining, and 3) the contribution of plant material to the macrodetritus pool for each vegetation type.

2.5.2 Litter Bags

2.5.2.1 *Field Collection*

Standing dead *P. arundinacea* and *C. lyngbyei* plants were collected in the field in the winter and kept in a cold room until ready for deployment in the litter bags in April. Litter bags were constructed of a fine mesh (130 µm) and a large mesh (2000 µm), sewn on all sides using nylon thread to have an interior dimension of 15 cm by 15 cm. The smaller mesh size was designed to allow decomposition by bacterial and physical processes, while limiting the decomposition by macroinvertebrates. In order to adequately represent the leaf to stem ratio of each plant type, we randomly selected 15 plants and weighed the stems and the leaves separately. The leaf:stem ratio was 36:64 for *P. arundinacea* and 99:1 for *C. lyngbyei*. The material was air dried at 30°C prior to placement in the bags. The fine-mesh bags were filled with 3 g of plant material and the large-mesh bags with 5 g using the pre-determined ratios of leaf and stem material for each plant type. Two bags of each mesh size were deployed at each site (except CALY6) in early April. One large and one fine-mesh bag were collected from each site in June (73-77 days) and in August (118-122 days). Three *P. arundinacea* and three *C. lyngbyei* samples were dried at 30°C and not deployed in the field. The samples were kept in a cold room until after the first field collection in June.

2.5.2.2 *Lab Processing and Analysis*

After retrieval from the field, any detritus or sediment on the outside of the bags was removed and the bags were rinsed with freshwater over a 355 µm sieve. Samples were then examined under a microscope and all macroinvertebrates were removed, preserved in 10 percent formalin, and sent to the University of Washington WET Lab for identification. After removal of the macroinvertebrates the fine-mesh samples were rinsed with freshwater over a 100 µm sieve and the large-mesh samples over a 500 µm sieve to remove mud but preserve fine organic material. All samples, including those held in the cold room, were air dried in a 30°C oven for one week then weighed. Samples were sent to ALS where they were analyzed for carbon (C) and nitrogen (N) content using standard EPA method 440.0. After sub-samples were removed for this analysis the samples were analyzed for percent moisture (ASTM method D2974-07a) and a final dry weight was calculated. For each site we calculated the average percent change in weight, the percent mass remaining, percent C, percent N, and C:N.

2.5.3 Macrodetritus

2.5.3.1 *Field Collection*

Macrodetritus samples were collected from each site in April and June to determine the amount of in situ detritus present at each site during the sampling period. A 13 cm core was used to collect the top 1 cm of sediment from four sample locations within each site.

2.5.3.2 *Lab Processing and Analysis*

The samples were rinsed with freshwater over a 500 µm sieve to remove mud but preserve fine organic material. All live material, such as roots, was removed from the samples. The type of vegetation in the samples was noted when possible. Samples were air dried in a 30°C oven for one to two weeks and weighed. Samples were then sent to ALS where the samples were analyzed for C and N content using standard EPA method 440.0. After sub-samples were removed for this analysis the samples were analyzed for percent moisture (ASTM method D2974-07a) and a final dry weight was calculated. For each site we calculated the average dry weight, percent C, percent N, and C:N.

2.6 Macroinvertebrate Sampling

2.6.1 Field Data Collection

Three techniques were employed to sample the invertebrate community within each study site: fallout traps, emergence traps, and benthic cores. These techniques were selected in order to obtain data on the different ecologies and/or life history stages of invertebrates that utilize different aspects of the marsh (e.g., soil-dwelling vs. aerial, aquatic vs. terrestrial). Within each sampling site, at each subsampling point, a fallout trap and an emergence trap were placed opposite each other on either side of the transect (Figure 2). Benthic cores were collected on the transect line in between the two traps (Figure 2). Weather during trap deployment was noted, as conditions can affect observed insect densities (e.g., Williams 1961, Briers et al. 2003). A power analysis conducted using neuston tow data collected in prior years of status and trend monitoring in the lower river concluded that sampling six sites of each vegetation type (*P. arundinacea* and *C. lyngbyei*) would be sufficient to statistically detect a doubling of the square root of the mean fly abundance between the two vegetation types. Five samples of each type were collected at the two longest sites (PHAR3 and PHAR5), and four samples of each type were collected from all other sites.

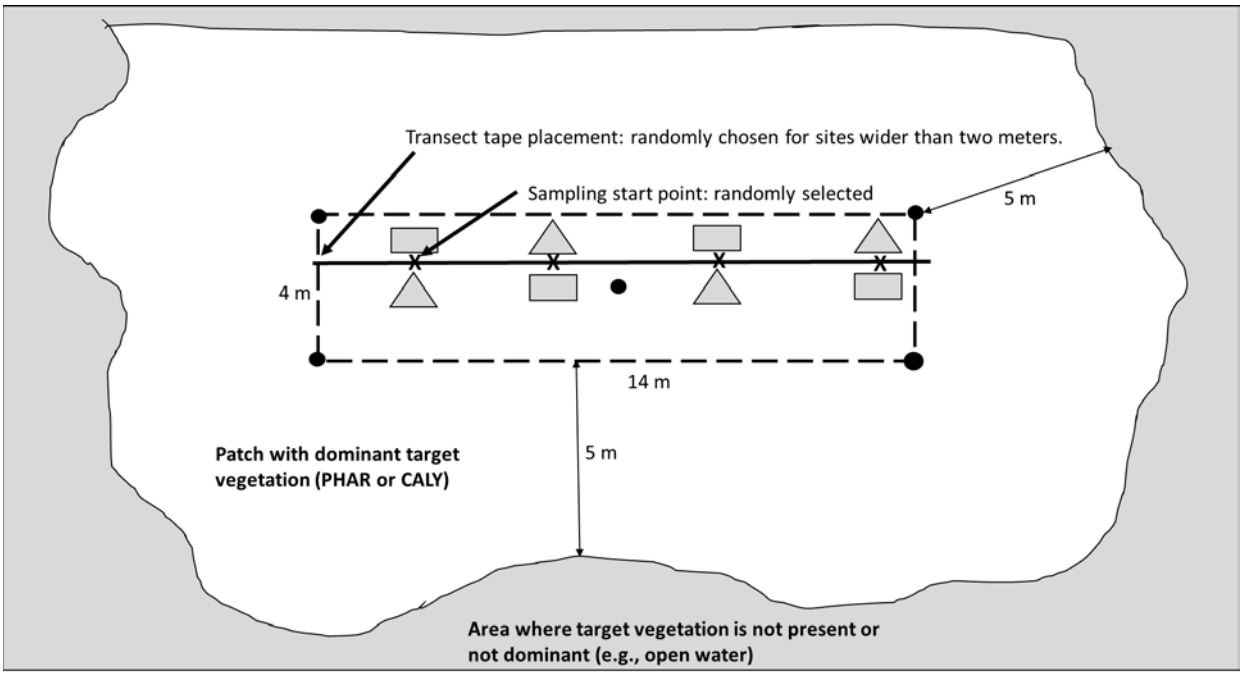


Figure 2. Simplified diagram of sampling setup at a site (site dimensions are an example only). The solid black line represents the transect tape. Gray rectangles = fallout traps and gray triangles = emergence traps. X's indicate the randomly selected sampling locations and the location of benthic cores. Filled black circles represent the PVC poles placed as markers at the corner and center of each site.

2.6.1.1 *Fallout Traps*

Fallout traps were used to sample terrestrial invertebrates such as aerial adult insects and spiders. Traps consisted of rectangular plastic bins (34 cm x 23 cm) filled with sufficient water to cover the entire trap bottom (typically about 2 inches deep). A drop of biodegradable soap was added to decrease surface tension and help retain insects collected in the trap. Each trap was placed on a PVC platform and secured to four PVC poles using metal rings and zip ties, allowing the trap to float up on the pole structure during high tide (Figure 3). Traps were deployed for approximately 24 hours and collection times for each trap were recorded. At the end of the trapping period, trap contents were collected through a 106 μm sieve and fixed in 10% formalin.

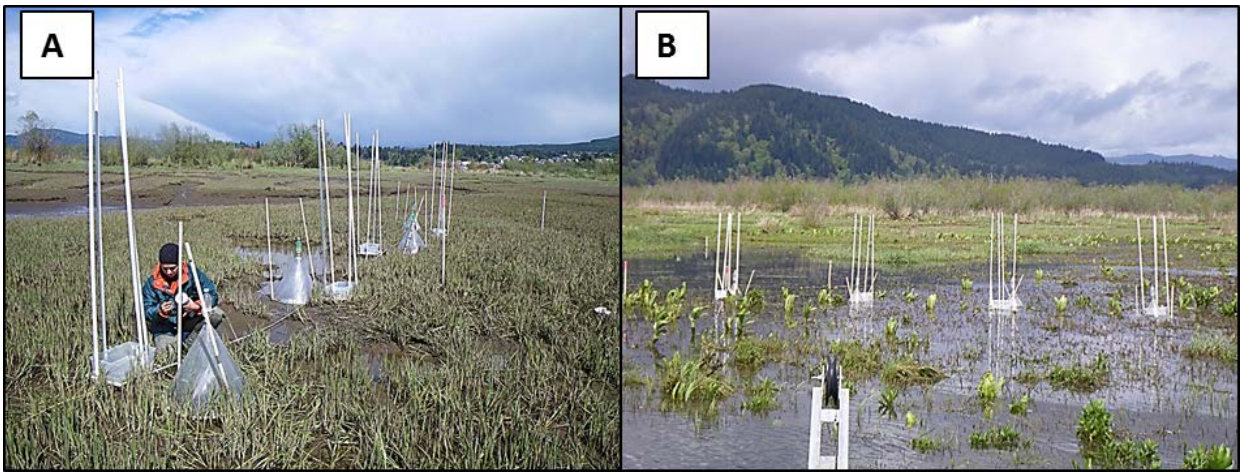


Figure 3. Fallout trap and emergence trap used to collect invertebrates at a) low tide and b) high tide.

2.6.1.2 *Emergence Traps*

Emergence traps were used to sample invertebrates emerging from the soil, such as flies metamorphosing from pupae to adults. In a prior study on the lower Columbia River estuary, Ramirez (2008) found that these traps successfully sampled emergent insect prey such as Chironomid flies in freshwater wetland habitats and also provided definitive information about specific habitat associations for prey. Traps consisted of clear plastic cones covering a base area of 0.6 m^2, and fitted with a modified plastic beverage bottle at the top to capture invertebrates (Figure 3). Each plastic bottle was filled approximately one-third full with soapy water to help trap invertebrates. Traps were secured to the marsh surface using two PVC poles and zip ties. Traps were deployed for approximately 24 hours and the set and collection time for each trap was recorded. At the end of the trapping period, trap contents were collected through a 106 µm sieve and fixed in 10% formalin.

2.6.1.3 *Benthic Cores*

Benthic cores were used to sample soil invertebrates such as worms and larval flies. Cores were collected to a depth of 10 cm by driving a 5.1 cm (2 inch) diameter PVC pipe into the ground at each sampling location. Each core was then placed in a jar and fixed in 10% formalin. Cores were sieved through a 500 µm sieve in the laboratory to remove sediment and then fixed again in 10% formalin to prepare for sample processing.

2.6.2 Macroinvertebrate Sample Processing

Fallout trap, emergence trap, and benthic core samples were collected successfully from all twelve sites in all three sampling months; however, a few within-site replicate samples were lost each month when traps were compromised by stormy weather, floating debris, or implementation errors in preservation protocols (Appendix D).

Invertebrates collected in fallout traps, emergence traps, and benthic cores were identified in the lab using high-resolution optical microscopy and taxonomic references (Mason 1993, Kozloff

1996, Merritt and Cummins 1996, Thorp and Covich 2001, Triplehorn and Johnson 2005). Most individuals were identified to family, although some groups/individuals were identified to coarser (e.g., order) levels. Adults of the fly family Chironomidae (midges) were further divided into morphotypes. For each sample, the number of individuals in each taxonomic group was counted, then each group was blotted dry and weighed to the nearest 0.0001 g.

Analyses of fallout trap data included all invertebrates with terrestrial or unknown ecology. Taxa that were known to be aquatic were considered contaminants and were excluded from analyses. Analyses of emergence trap data included invertebrates of all ecologies. Since benthic organisms were sampled by benthic cores, Cladocera, Nematoda, Oligochaeta, Ostracoda, Gastropoda (slugs, snails), and Hirudinea were also excluded from fallout and emergence trap analyses. In benthic core samples, taxa that were not aquatic and/or benthic in their ecology were considered contaminants and were excluded from analyses of benthic core data (e.g., adult flies).

2.7 Statistical Analysis

2.7.1 Vegetation Assemblage, Production and Decomposition Analysis

Descriptive statistics of each variable for each vegetation patch type and month were calculated. Univariate ANOVA with main effects of Month and Vegetation Type (Dom-Plant) and the interaction Month*Type was used to examine the quantity and quality of detritus; decomposition rates; and above ground plant biomass production between the patches of *P. arundinacea* versus *C. lyngbyei*. Covariates including the percent fine sediment, TOC, distance to the river mainstem, distance to other plant communities, patch area to wetland area ratio, site location (rkm along the Columbia River), and site inundation in June (percent of time) were evaluated using linear regression as potential explanatory variables.

The Bray-Curtis similarity coefficient (S'):

$$\frac{\sum_{i=1}^{i=n} |s_{i1} - s_{i2}|}{\sum_{i=1}^{i=n} (s_{i1} + s_{i2})}$$

was used as a measure of distance between sites using the PRIMER (Plymouth Routines In Multivariate Ecological Research) software package developed at the Plymouth Marine Laboratory (Clarke and Warwick 1994; Clarke and Gorley 2006). The coefficient S', ranges from 0 (if two sites-month have no species in common) to 1 (if two sites-month have all species at the same abundance). The Bray-Curtis pairwise similarity between average August landscape scale plant cover was calculated using all species, all species except *C. lyngbyei* and *P. arundinacea*,

and using only those taxa that explained at least 10% of the variability. Data were transformed to the log10(+1).

Similarity was also calculated between August patch cover and landscape cover with and without *C. lyngbyei* and *P. arundinacea* in the analysis. A non-metric, multi-dimensional scaling (MDS) ordination plot was used to show similarity in two or three dimensions. Observations are iteratively positioned in space until the distance between observations agrees with their similarity (measured by a stress statistic). Stress is a measure of the goodness-of-fit of a nonparametric regression of the similarity on the inter-object distances in n-dimensional space. Small stress values ($0 < \text{stress} < 0.1$) indicate that the distances between points on the nMDS plot closely match the similarity values from the Bray-Curtis matrix. For stress values approaching 0.2, significant differences among groups may not be immediately obvious in the nMDS plots and would only be visible in a three or more dimensional plot. The final orientation between observations in the nMDS plot is arbitrary and relates to the relative distances between observations. ANOSIM, an ANOVA-like nonparametric test of the difference between groups based on the similarity, was used to evaluate differences between dominant plant site types (CALY vs PHAR sites) and between patches and landscapes using PRIMER software. ANOSIM conducts all possible pair-wise comparisons between groups.

2.7.2 Macroinvertebrate Analysis

Descriptive and inferential statistical analyses of the whole invertebrate community were completed, in addition to specific analyses of the entire order Diptera (flies) fly family and Chironomidae (midges). Previous research in the Cathlamet Bay area of the lower Columbia River has shown that emerging and adult chironomids are the primary prey of small juvenile Chinook salmon (40-79 mm FL) in emergent marshes, although larval chironomids may also be consumed. Chironomids also make up a large proportion of the diets of larger juvenile Chinook salmon (80-121 mm FL); however, diets generally become more diverse as Chinook salmon grow (Lott 2004, Spilseth and Simenstad 2011). Therefore, evaluating differences in chironomid density and biomass in different types of emergent marsh vegetation is important for inferring effects on juvenile salmonid food webs. Due to high occurrences of the subclass Collembola (springtails), statistical analyses of the taxon were also completed for fallout and emergence trap abundance data.

For fallout and emergence traps, the density and biomass of taxa in each sample were calculated as the total count or weight for a given taxon divided by the trap surface area and trapping time (# individuals/m^2/hour, mg/m^2/hour). For benthic cores, the density and biomass of taxa in each sample were calculated as the total count or weight (mg) for a given taxon by the core volume (approximately 200 cm^3). In order to compare taxa densities and biomass between study sites, density and biomass data for each taxon were summed across replicate samples taken within a given site each month, then divided by the number of replicates and the average trapping time to

give an average total density and biomass at each sampling site per month. Because the variance in average density and biomass data was not equal between the two vegetation types in all months, data were transformed to the square root (abundance data) or to the natural log (+1) (biomass data) to achieve equal variance before calculating measures of effect size. Effect size was calculated as Hedges' *g*, which uses Cohen's *d* with a pooled estimate for standard deviation and an adjustment for small-sample bias, as in Nakagawa and Cuthill (2007, Table 1 and equation 14). Confidence intervals (CI) on Hedges' *g* were calculated using equations 17 and 18 in Rosnow and Rosenthal (2009). In general, confidence intervals may be interpreted as a likely range for a given population parameter, and effect size is simply the magnitude of the difference between two groups (Nakagawa and Cuthill 2007). The Shannon Index (H') was used to compare values of taxonomic diversity among vegetation types, with higher H' values corresponding to greater diversity.

Univariate ANOVA with main effects of Month and Vegetation Type (Dom-Plant) and the interaction Month*Type was used to examine the abundance and biomass of invertebrates between *P. arundinacea* and *C. lyngbyei* dominated sites; the covariate percent fines was also assessed. Abundance data were transformed to the square root and biomass was transformed to the natural log (+1) to reduce within class heterogeneity. When the interaction term Month*Type was significant, a one-way ANOVA was conducted on the Month-Type groupings. The Kruskal-Wallis nonparametric ANOVA on the Month-Type groupings was used when the variances of the transformed data were not equal.

Multivariate analyses were used to examine within month differences in the invertebrate assemblage between vegetation types. Taxa that did not contribute at least five percent to any of the samples were removed from analysis. We calculated similarity indices for the average site abundance and biomass invertebrate taxa using the Bray-Curtis similarity coefficient (S') as a measure of distance between sites. The density data were square root transformed and biomass data were transformed the natural log (+1) transformed.

A non-metric, multi-dimensional scaling (nMDS) ordination plot was used to show similarity in two or three dimensions. To test of the difference between groups based on the similarity, an ANOSIM was used to evaluate differences between months and plant-month combinations for invertebrate metrics using PRIMER software. A Bonferroni correction was applied to the family error rate ($\alpha = 0.05$) to calculate an individual comparison error rate (e.g., three pair-wise month comparisons; 15 pair-wise plant-month comparisons) such that significance was detected for month comparisons with a p-value less than $\alpha/3 = 0.0167$, and plant-month comparisons with a *p*-value less than $\alpha/15 = 0.003$.

A regression analysis was conducted to evaluate the influences of the landscape cover of *C. lyngbyei* (which occurred in all landscapes), as measured in August 2014, on the invertebrate community as observed in fall out traps, emergent traps, and benthic cores. Because the variance in average density and biomass data was not equal between the two vegetation types in all months, data were

transformed to the square root (density data) or to the natural log (+1) (biomass data) to achieve equal variance before regressing against the cover data.

3 Results

3.1 Environmental Controlling Factors

3.1.1 Substrate

Sediment grain size at the sample sites was comprised primarily of silt and sand (Figure 4). Seven of the 12 sites were comprised of fine sediments with greater than 50 percent silt and seven to 13 percent clay, while four of the sites had more coarse sediments consisting of greater than 50 percent medium and fine sand. The remaining site, CALY6 at rkm 62, was a more even mix of these constituents. Total organic carbon (TOC) at the sample sites ranged from less than one percent to 6.8 percent at CALY2 (Figure 4), with the lowest percentage at the four sites with more coarse grain size constituents.

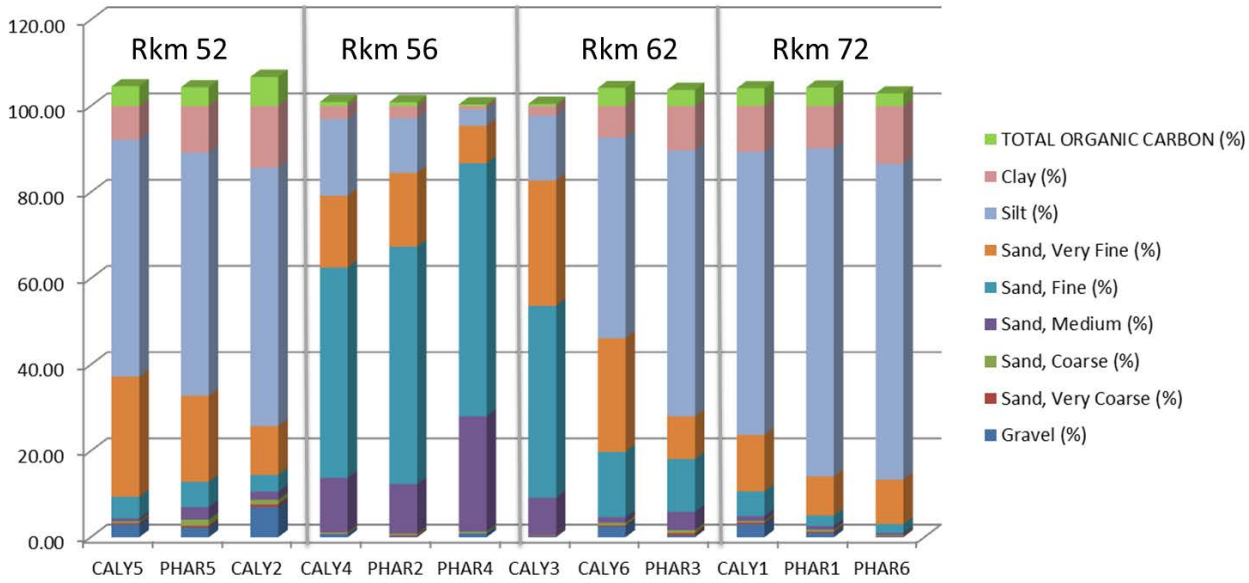


Figure 4. Percent (%) sediment grain size and total organic carbon at the twelve sample sites. Sites are ordered by river kilometer (rkm) from lowest to highest in the study area.

3.1.2 Elevation

By design, the elevation of the sites covered a narrow range, with the sample sites ranging from 1.45 m to 1.76 m, CRD (Table 1). The marshes in which the sample sites were located between the elevations of 0.84 m and 1.93 m, CRD. The average elevation of *P. arundinacea* at the sites was between 1.36 m and 1.95 m, while the elevation range of *C. lyngbyei* was between 1.07 m and 1.74 m, CRD.

3.1.3 Hydrology and Inundation

The percent of time that each site was inundated during the two weeks prior to each invertebrate sampling event varied from a low of 24% in June at CALY2 to a high of 59% in May at PHAR6 (Figure 5). Inundation was negatively correlated with elevation (-0.84 in April, -0.70 in May, and -0.76 in June) and positively correlated with river kilometer (0.55 in April, 0.76 in May, 0.71 in June).

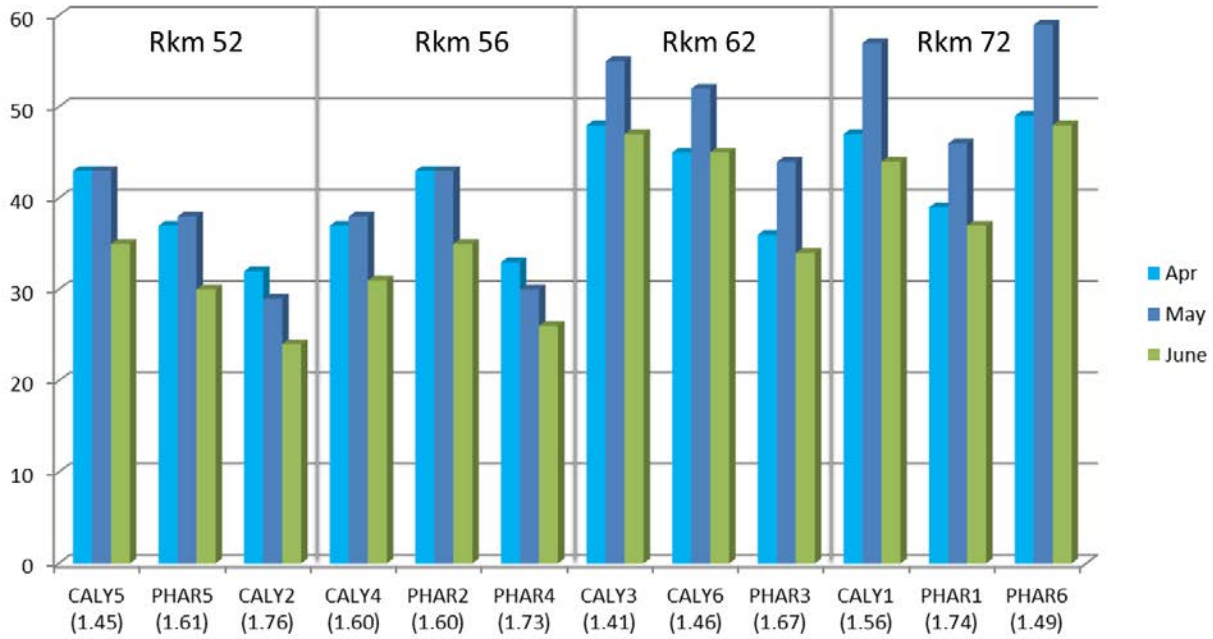


Figure 5. Frequency of inundation of the sample sites each month during the two week period prior to macroinvertebrate sampling. Average elevations of the sites are in parentheses below the site name. Sites are ordered by river kilometer (Rkm) from lowest to highest in the study area.

3.2 Vegetation Species Assemblage

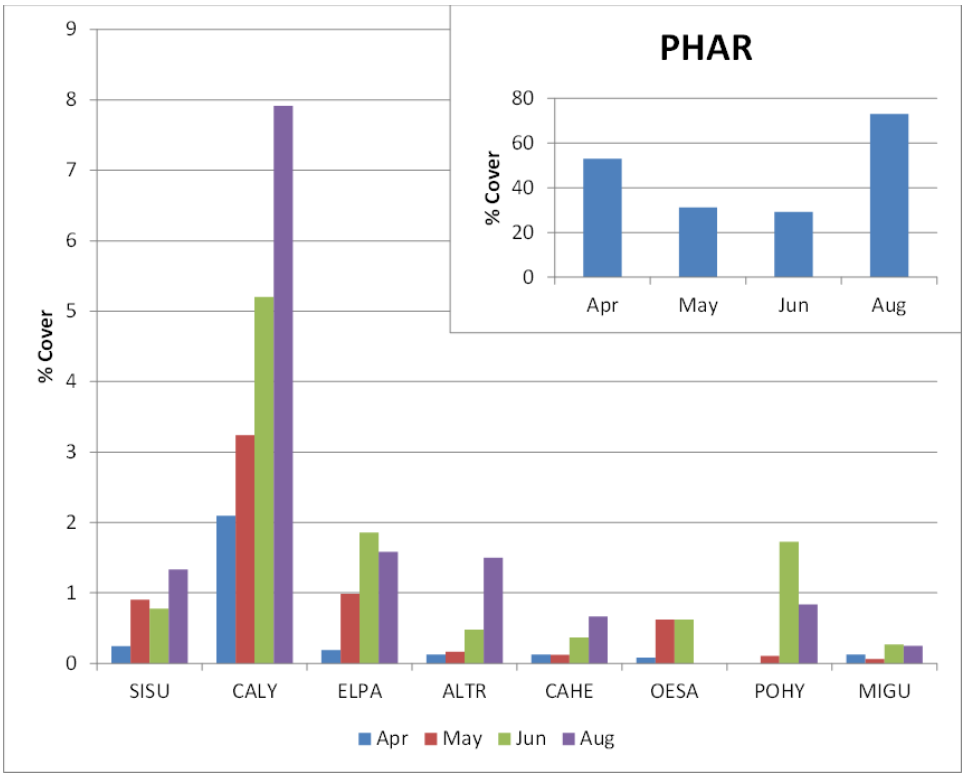
The vegetation assemblages were analyzed at the site scale (i.e., within the sampling site) and at the landscape scale, which included the wetland area surrounding the sample site.

3.2.1 Site Scale

Not surprisingly, the two types of sample sites (CALY and PHAR) had significantly different vegetation from each other when all taxa were included in the analysis (ANOSIM; $p = 0.001$), with the PHAR sites predominantly *P. arundinacea* and the *C. lyngbyei* sites dominated by *C. lyngbyei* (Figure 6). Without *C. lyngbyei* and *P. arundinacea* and considering only those plants that were observed in at least 10 sites (ELPA, CAHE, SISU, POHY, MIGU, and OESA; see Appendix C for definition of the species codes) sites were still significantly different ($p = 0.042$). Dominant plants based on the occurrence (number of sites) after *P. arundinacea* and *C. lyngbyei* were SISU and CALY in *P. arundinacea* sites and ELPA and CAHE in *C. lyngbyei* sites. April

and June had significantly different in-patch vegetation using all taxa for both *P. arundinacea* and *C. lyngbyei* sites (ANOSIM; p = 0.004 and p = 0.002 respectively). Percent cover of *P. arundinacea* significantly decreased by month (p = 0.005), *C. lyngbyei* increased over the study period and was nearly significantly different (p = 0.051). In the *P. arundinacea* sites, bare ground and detritus increased over time, while they decreased over time in the *C. lyngbyei* sites (Figure 7).

a)



b)

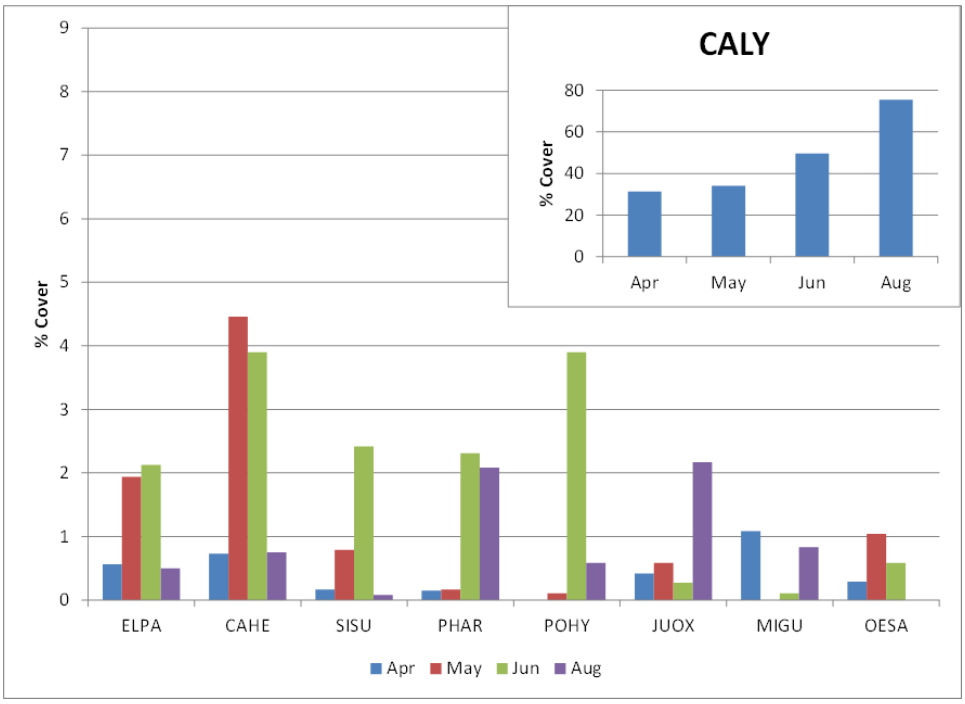


Figure 6. Average percent cover of a) *P. arundinacea* (PHAR) and other species; and b) *C. lyngbyei* (CALY) and other species present in the sample sites. Species codes and percent covers are provided in Appendix C.

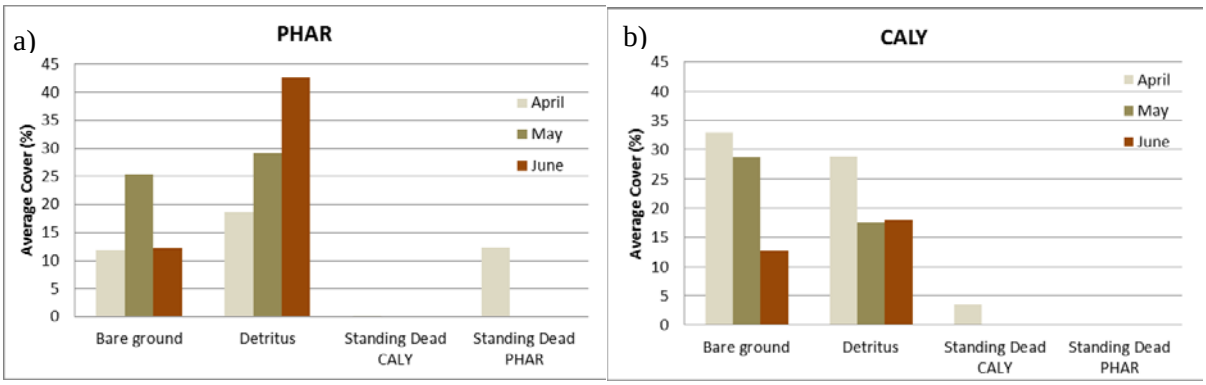
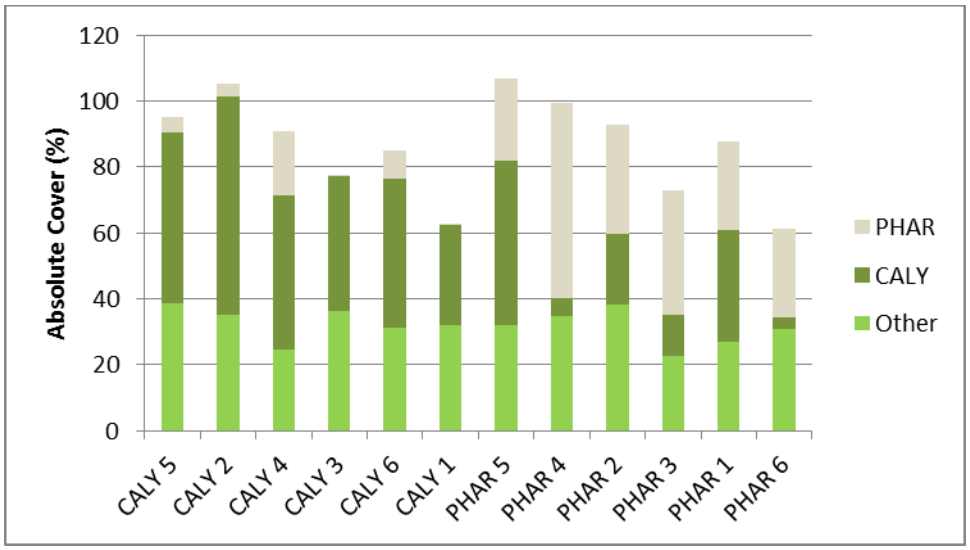


Figure 7. Average percent cover of bare ground, detritus, and standing dead in a) *P. arundinacea* (PHAR) sites and b) *C. lyngbyei* (CALY) sites.

3.2.2 Landscape Scale

In the wetland landscape encompassing the sample sites, *P. arundinacea* and *C. lyngbyei* accounted for 63 percent of the cover (Figure 8a). *C. lyngbyei* was present at all the sites, but cover was generally highest at the CALY sites. Likewise, the same was true for *P. arundinacea*, with highest cover occurring in PHAR sites and relatively little cover in CALY sites. Overall there was greater cover of *C. lyngbyei* in PHAR sites than there was *P. arundinacea* in CALY sites. Nine other species were prominent in the species assemblage, comprising between 13 and 28 percent of the total cover (Figure 8b). The number of identified species ranged from 18 to 43 per site, with a total of 69 species identified from all the sites.

a)



b)

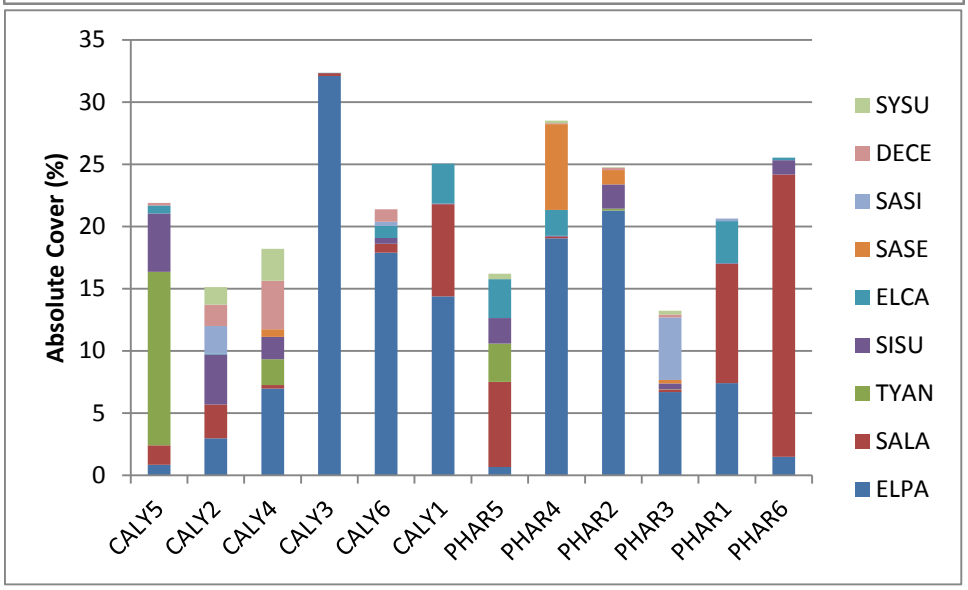


Figure 8. Average percent cover of a) *P. arundinacea* (PHAR), *C. lyngbyei* (CALY), and other species; and b) breakdown of cover for nine other species present at the landscape scale. Species codes and percent cover for all species are provided in Appendix C. Sites are ordered by river kilometer (rkm) from lowest to highest in the study area.

At the landscape scale, all the sites within the study area were on average 53% similar to each other when all species were used in the analysis. The most similar sites were those in closest proximity to each other, PHAR1 and CALY1, at 75% similarity. Comparison of the types of sites yields similar results, with *C. lyngbyei* sites 53% similar to each other, *P. arundinacea* sites 57% similar to each other, and *C. lyngbyei* sites 51% similar to *P. arundinacea* sites.

3.3 Vegetation Production and Decomposition

As a first step in the analysis of the vegetation production and decomposition metrics, the covariates were evaluated as explanatory variables. The covariates of percent fines and site location (as measured by river kilometer) were the only ones found to be explanatory variables. In the analyses, any linear relationship between the variable of interest and the covariate were removed before a comparison between the major effects of plant type or sampling period and their interaction was tested. Percent fines and percent total organic carbon content (TOC) were found to be correlated (0.81) and therefore only percent fines was used as a covariate in the analyses.

3.3.1 Above Ground Vegetation Biomass

The above ground biomass collected at the latter part of the growing season can be used as a proxy for estimating the peak productivity and standing stock. Likewise, the remaining standing stock collected at the end of winter, prior to spring growth, can be subtracted from the summer peak standing stock to estimate how much organic material broke off during the winter and is being contributed to the detrital pool. The summer biomass results were highly variable, especially the *P. arundinacea* (Table 3), where individual samples (n = 4 samples were collected from each of the 12 sites) ranged from 1 g/m^2 to over 2300 g/m^2. *C. lyngbyei* samples were slightly less variable, but individual samples still had a range of nearly 1500 g/m^2. The Kruskal-Wallis test found that there was no statistically significant difference in the above ground biomass in the summer between *C. lyngbyei* and *P. arundinacea* (Figure 9). Winter standing stock was lower than summer standing stock and was significantly lower in *C. lyngbyei* compared to *P. arundinacea* (Kruskal-Wallis p = 0.037). The mean detrital contribution from *C. lyngbyei* was similar to that of *P. arundinacea* (Kruskal-Wallis; p = 0.20); however, the ratio of winter to summer biomass was nearly significantly different (Kruskal-Wallis; p = 0.055; Figure 9).

Table 3. Descriptive statistics for the above ground summer and winter biomass samples from the two vegetation types at each sampling site (CALY, n = 6; PHAR, n = 6).

Variable	Type	n	Mean	StDev	Min	Q1	Median	Q3	Max	CV
Summer Biomass (g/m^2)	CALY	6	1002.1	166.9	774.9	894.9	969.4	1138	1269.5	17%
	PHAR	6	936	268	653	728	859	1192	1355	29%
Winter Biomass (g/m^2)	CALY	6	121.3	89.2	14.4	54.1	95.8	220.6	240.5	74%
	PHAR	6	295.6	192.9	116.4	153.3	257.4	402.1	660.8	65%
Contribution (g/m^2)	CALY	6	880.7	241.7	534.4	674.3	874.6	1109.8	1200.1	27%
	PHAR	6	641	377	92	329	643	948	1190	59%
Ratio Winter:Summer	CALY	6	0.13	0.11	0.013	0.044	0.098	0.249	0.310	85%
	PHAR	6	0.35	0.28	0.12	0.14	0.28	0.50	0.88	79%

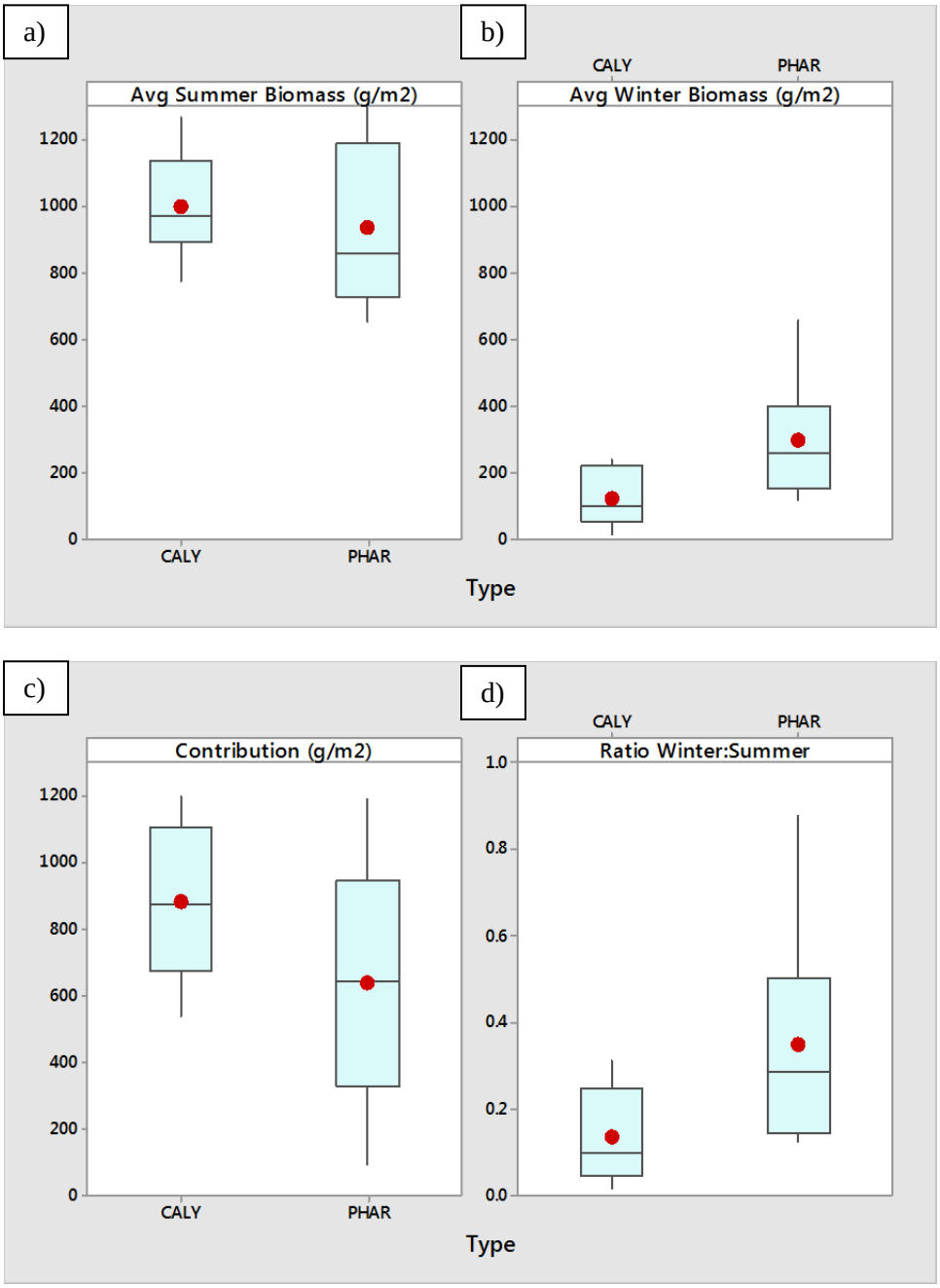


Figure 9. Boxplot of the results for average a) summer and b) winter above ground biomass and the average c) potential contribution and d) ratio of winter to summer organic material in *P. arundinacea* (PHAR) and *C. lyngbyei* (CALY) sites.

3.3.2 Litter Bags

Descriptive statistics for decomposition metrics of the small and large mesh size litter bags, including the percent change in weight, decay rate, and carbon (C) to nitrogen (N) ratio, are provided in Table 4 and Table 5. The large mesh size bags gained weight between April and June because organic material entered the bags during that time period. The extent that this occurred is not known, however the effect was more evident in the *P. arundinacea* bags (Table 5).

Table 4. Descriptive statistics for decomposition metrics of *C. lyngbyei* and *P. arundinacea* in the small mesh bags.

Variable	Month	n	Mean	StDev	Min	Q1	Median	Q3	Max
C. lyngbyei									
% Change in Weight	June	5	25.7	12.7	8.2	12.9	30.5	36.0	40.1
	Aug	5	48.2	3.7	44.0	44.3	49.8	51.4	51.8
Decay Rate (g/day)	June	5	0.010	0.005	0.003	0.005	0.012	0.014	0.015
	Aug	5	0.012	0.001	0.011	0.011	0.012	0.013	0.013
C:N	June	5	20.7	3.1	17.7	18.2	19.2	24.1	24.1
	Aug	5	19.8	1.6	18.3	18.7	19.5	21.1	22.5
P. arundinacea									
% Change in Weight	June	6	27.5	13.7	5.7	17.8	28.2	38.0	46.0
	Aug	6	40.0	11.4	20.3	32.5	40.9	49.2	53.0
Decay Rate (g/day)	June	6	0.011	0.005	0.002	0.007	0.011	0.015	0.018
	Aug	6	0.010	0.003	0.005	0.008	0.010	0.012	0.013
C:N	June	6	39.6	8.1	29.8	34.4	38.6	44.1	54.1
	Aug	6	31.2	5.9	22.6	27.2	30.1	37.1	39.3

Stats?

Table 5. Descriptive statistics for decomposition metrics of *C. lyngbyei* and *P. arundinacea* in the large mesh bags.

Variable	Month	n	Mean	StDev	Min	Q1	Median	Q3	Max
C. lyngbyei									
% Change in Weight	June	5	25.1	29.5	-24.0	-1.0	34.7	46.5	52.2
	Aug	5	49.1	17.0	32.6	33.1	46.4	66.4	70.3
Decay Rate (g/day)	June	5	0.010	0.011	-0.009	0.000	0.014	0.018	0.020
	Aug	5	0.012	0.004	0.008	0.008	0.011	0.016	0.017
C:N	June	5	19.0	0.6	18.4	18.4	19.1	19.6	19.9
	Aug	5	18.8	1.9	16.9	17.1	18.5	20.7	21.6
P. arundinacea									
% Change in Weight	June	6	-14.1	21.6	-38.3	-29.4	-21.8	8.2	19.5
	Aug	6	26.1	17.6	2.6	5.5	31.9	39.5	46.4
Decay Rate (g/day)	June	6	-0.006	0.009	-0.015	-0.012	-0.008	0.003	0.008
	Aug	6	0.006	0.004	0.001	0.001	0.008	0.010	0.011
C:N	June	6	23.1	3.7	19.3	20.5	22.2	25.5	29.8
	Aug	6	26.3	4.9	20.3	21.4	26.1	31.4	32.7

The *C. lyngbyei* organic material in the large mesh bags had a significantly greater reduction in weight than the *P. arundinacea* material (p = 0.004; Figure 10) and both plant types had a significantly greater change in weight over the longer deployment period (p = 0.003). In the small mesh bags, there was no significant difference in weight change between the plant types, however there was a significantly greater weight change for both plant types in the April to August time period compared to April to June (p = 0.002).

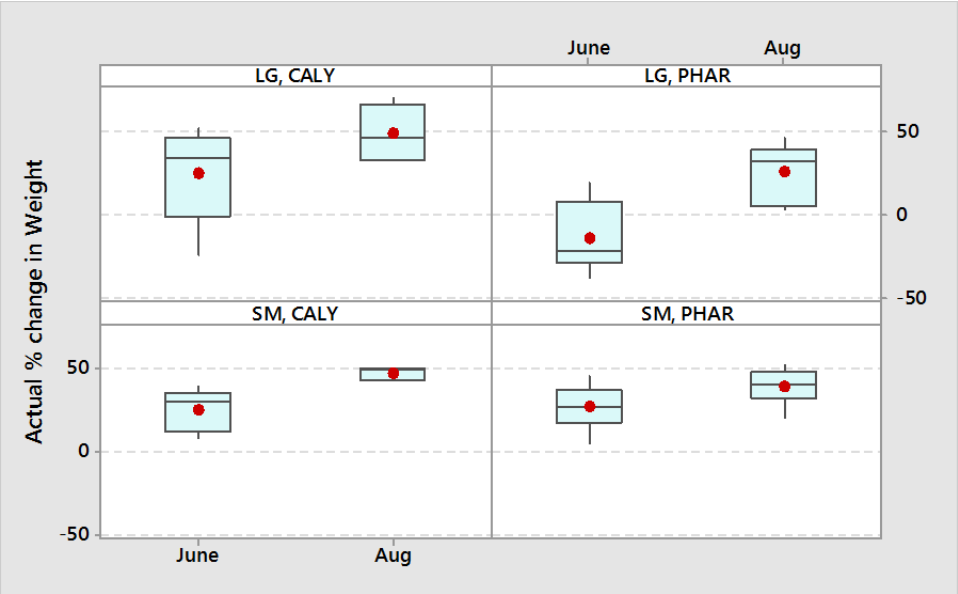


Figure 10. Boxplot of results for the percent change in weight of the material in large and small mesh size litter bags for each plant type between April and June and between April and August.

Similar to the percent change in weight, the decay rate was also significantly higher in the large mesh bags with *C. lyngbyei* compared to those with *P. arundinacea* (p = 0.005; Figure 11). In both plant types, the decay rate was greater for the longer deployment period (p = 0.045). In the small mesh bags, there was no significant difference in the decay rates of each plant type or for the time periods they were deployed.

P. arundinacea organic material had a significantly higher carbon to nitrogen ratio (C:N) than *C. lyngbyei* in both small mesh size (p = 0.000) and large mesh size (p = 0.001) litter bags (Figure 12). The difference in the C:N between retrieval periods was not significant in the large mesh bags, but was nearly significant in the small mesh bags (p = 0.063).

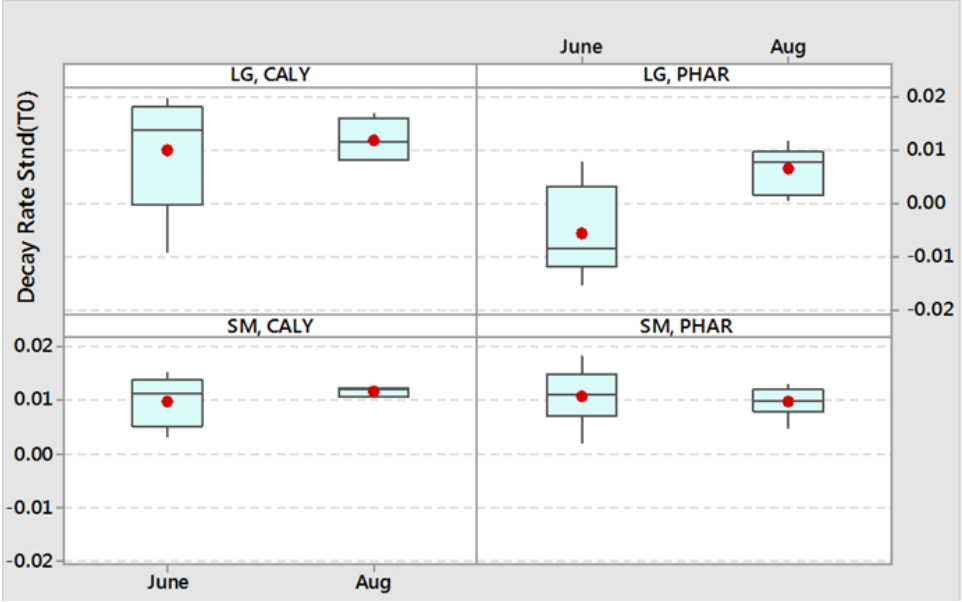


Figure 11. Boxplot of results for the decay rates, standardized for weights at time 0, of the material in large and small mesh size litter bags for each plant type between April and June and between April and August.

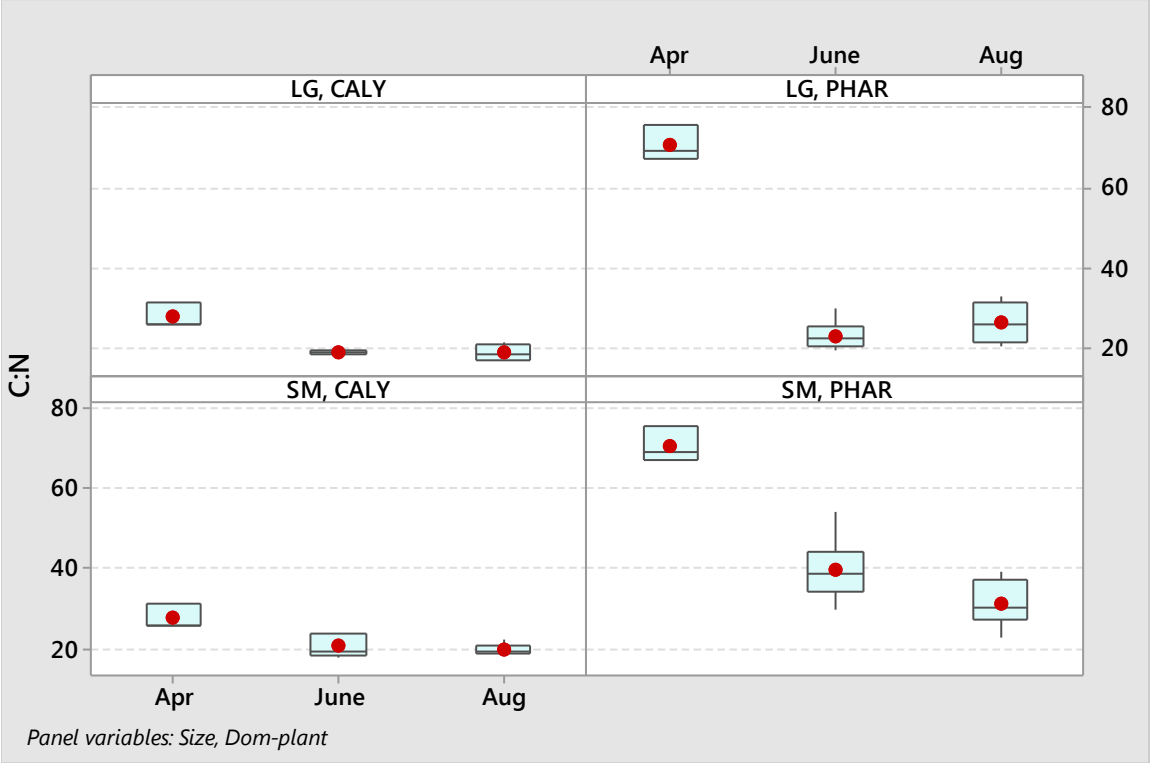


Figure 12. Boxplot of results for C:N of the material in large and small mesh size litter bags for each plant type after retrieval in June and in August.

Some interesting patterns are evident in the carbon and nitrogen content of each species over time and in the different litter bag sizes (Figure 13). Initially carbon was higher in *P. arundinacea* and remained so in the small bags, however in the large mesh bags the content decreased to levels similar to that of *C. lyngbyei*. The carbon content declined in both species and mesh sizes over time. Nitrogen content of the *P. arundinacea* material was initially lower than that in the *C. lyngbyei* bags and remained so over time. The relative increase in nitrogen was greater in *P. arundinacea* so that levels were more similar to *C. lyngbyei* at the end of the study period.

Macroinvertebrates found in the litter bags were identified, counted, and weighed and the results were summarized into total taxa, juvenile salmon diet taxa, and taxa that are detritivores (decomposers). The number of species present was not significantly different between the plant types or the bag size. However, the small mesh litter bags placed in *C. lyngbyei* sites consistently had higher mean and median macroinvertebrate counts and weights than those placed in *P. arundinacea* sites (Table 6). The exception is for the median count of diet taxa in June in which the *P. arundinacea* count was slightly higher.

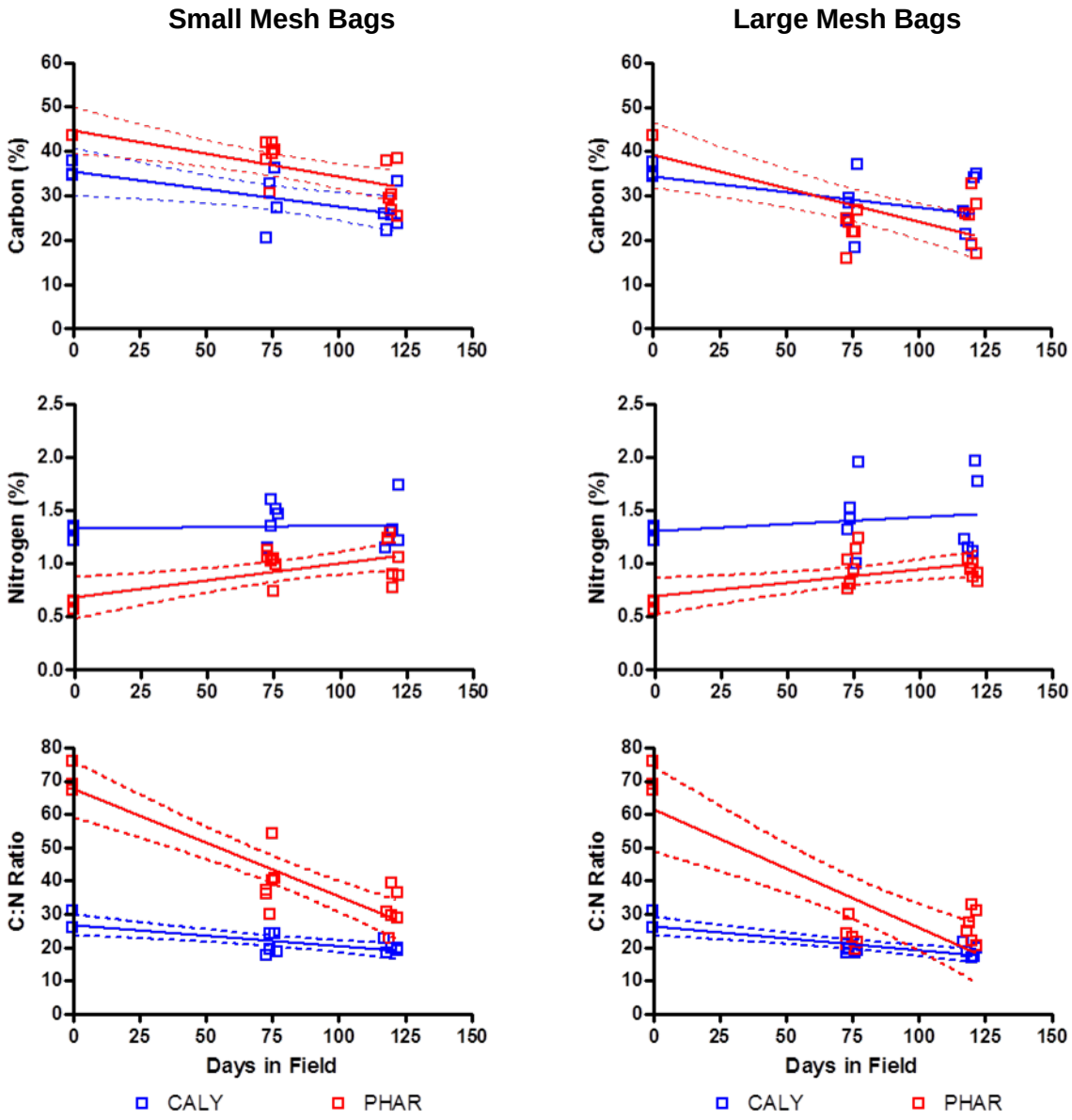


Figure 13. Percent carbon and nitrogen and the resulting C to N ratio over time in the large and small mesh litter bags.

Table 6. Descriptive statistics for the macroinvertebrate metrics of *C. lyngbyei* and *P. arundinacea* in the small mesh bags.

Variable	Month	n	Mean	StDev	Min	Q1	Median	Q3	Max
C. lyngbyei									
Total Taxa Count	June	5	64.0	39.8	6	25.5	69	100	101
	Aug	5	45.8	24.1	17	26	37	70	78
Diet Taxa Count	June	5	19.6	26.4	2	3	12	40	66
	Aug	5	7.0	6.8	1	1.5	7	12.5	18
Decomposer Count	June	5	58.8	37.9	5	22.5	61	94	94
	Aug	5	30.2	20.1	9	15.5	25	47.5	63
Total Taxa Wt. (mg)	June	5	5.6	3.6	1	2.3	5.4	9	10.3
	Aug	5	3.2	2.65	0.6	1.15	2.2	5.7	7.4
Diet Taxa Wt. (mg)	June	5	2.3	1.96	0.5	0.7	1.4	4.4	4.9
	Aug	5	0.6	0.5	0.2	0.3	0.5	1.1	1.4
Decomposer Wt. (mg)	June	5	4.3	3.4	0.9	1.9	3	7.5	9.7
	Aug	5	2.7	2.7	0.5	0.7	1.3	5.4	6.9
P. arundinacea									
Total Taxa Count	June	6	42.7	40.3	1	7.0	39.5	69.3	112
	Aug	6	28.5	18.2	2	10.3	33	42.0	51
Diet Taxa Count	June	6	12.7	8.4	1	3.3	15.5	19.5	21
	Aug	6	2.2	1.2	1	1.0	2	3.3	4
Decomposer Count	June	6	30.7	24.2	0	6.0	32.5	50.8	65
	Aug	6	13.7	7.9	2	8.8	13	19.3	26
Total Taxa Wt. (mg)	June	6	3.0	2.5	0.1	0.6	2.8	5.5	6.5
	Aug	6	1.9	2.0	0.4	0.6	1.1	3.4	5.6
Diet Taxa Wt. (mg)	June	6	1.6	1.5	0.1	0.2	1.4	2.7	4.1
	Aug	6	0.3	0.1	0.1	0.2	0.3	0.4	0.5
Decomposer Wt. (mg)	June	6	2.6	2.3	0.0	0.5	2.3	4.8	6.3
	Aug	6	1.6	2.0	0.4	0.4	0.9	2.7	5.5

The macroinvertebrate data from the large mesh bags was more variable then that of the small bags, with more than half the results indicating that the large bags in *C. lyngbyei* sites had higher counts and weights than those in the *P. arundinacea* sites (Table 7). The mean and median total taxa and decomposer counts were higher in June from the *P. arundinacea* sites, while the mean and median total taxa and decomposer weights were higher in August.

Table 7. Descriptive statistics for the macroinvertebrate metrics of *C. lyngbyei* and *P. arundinacea* in the large mesh bags.

Variable	Month	n	Mean	StDev	Min	Q1	Median	Q3	Max
C. lyngbyei									
Total Taxa Count	June	5	43.2	58.3	6	8.5	22	88.5	146
	Aug	5	58.2	33.5	9	23.5	76	84.0	87
Diet Taxa Count	June	5	11.8	11.9	1	2.0	8	23.5	30
	Aug	5	9.2	8.2	3	3.0	4	18.0	20
Decomposer Count	June	5	38.2	55.7	4	7.0	19	79.0	137
	Aug	5	51.0	30.4	7	20.0	63	76.0	80
Total Taxa Wt. (mg)	June	5	239.0	271.0	43.0	59.0	162.0	457.0	710.0
	Aug	5	66.4	63.7	12.7	25.0	51.2	115.3	176.5
Diet Taxa Wt. (mg)	June	5	18.7	27.1	3.0	3.7	5.5	40.4	66.5
	Aug	5	3.5	2.4	0.9	1.8	2.9	5.5	7.5
Decomposer Wt. (mg)	June	5	221.0	274.0	37.0	53.0	139.0	429.0	703.0
	Aug	5	55.4	68.9	2.7	7.5	35.1	113.5	173.4
P. arundinacea									
Total Taxa Count	June	6	45.2	25.6	9	20.3	48	68.0	77
	Aug	6	29.8	16.1	13	16.0	25	47.8	53
Diet Taxa Count	June	6	10.7	9.0	2	2.0	8.5	21.3	22
	Aug	6	3.7	3.1	0	1.5	3	6.0	9
Decomposer Count	June	6	42.0	25.7	8	15.5	44.5	65.3	75
	Aug	6	25.8	14.3	10	15.3	20.5	43.3	44
Total Taxa Wt. (mg)	June	6	133.0	123.1	3.9	22.7	99.1	276.5	297.1
	Aug	6	175.3	122.7	57.0	62.5	148.0	294.1	363.3
Diet Taxa Wt. (mg)	June	6	5.3	4.5	0.7	1.2	4.5	9.2	12.5
	Aug	6	4.6	8.1	0.0	0.5	1.7	7.1	20.9
Decomposer Wt. (mg)	June	6	94.3	92.8	3.5	22.4	80.7	145.5	267.4
	Aug	6	129.7	82.5	57.0	61.9	101.6	205.7	270.4

A linear regression of covariates found that percent fines were an explanatory covariate for number of macroinvertebrates of all taxa present in the small bags and for the number of macroinvertebrates of diet taxa in the large bags. A general linear model was developed to account for the effect of the covariates. No significant differences in macroinvertebrate metrics were found in the large bags, however the number of macroinvertebrates of all taxa in small

mesh bags from the *C. lyngbyei* sites were significantly higher than those from the *P. arundinacea* sites (p = 0.048). The weight of the juvenile salmon diet taxa were significantly higher in June in the small bags compared to August (p = 0.012).

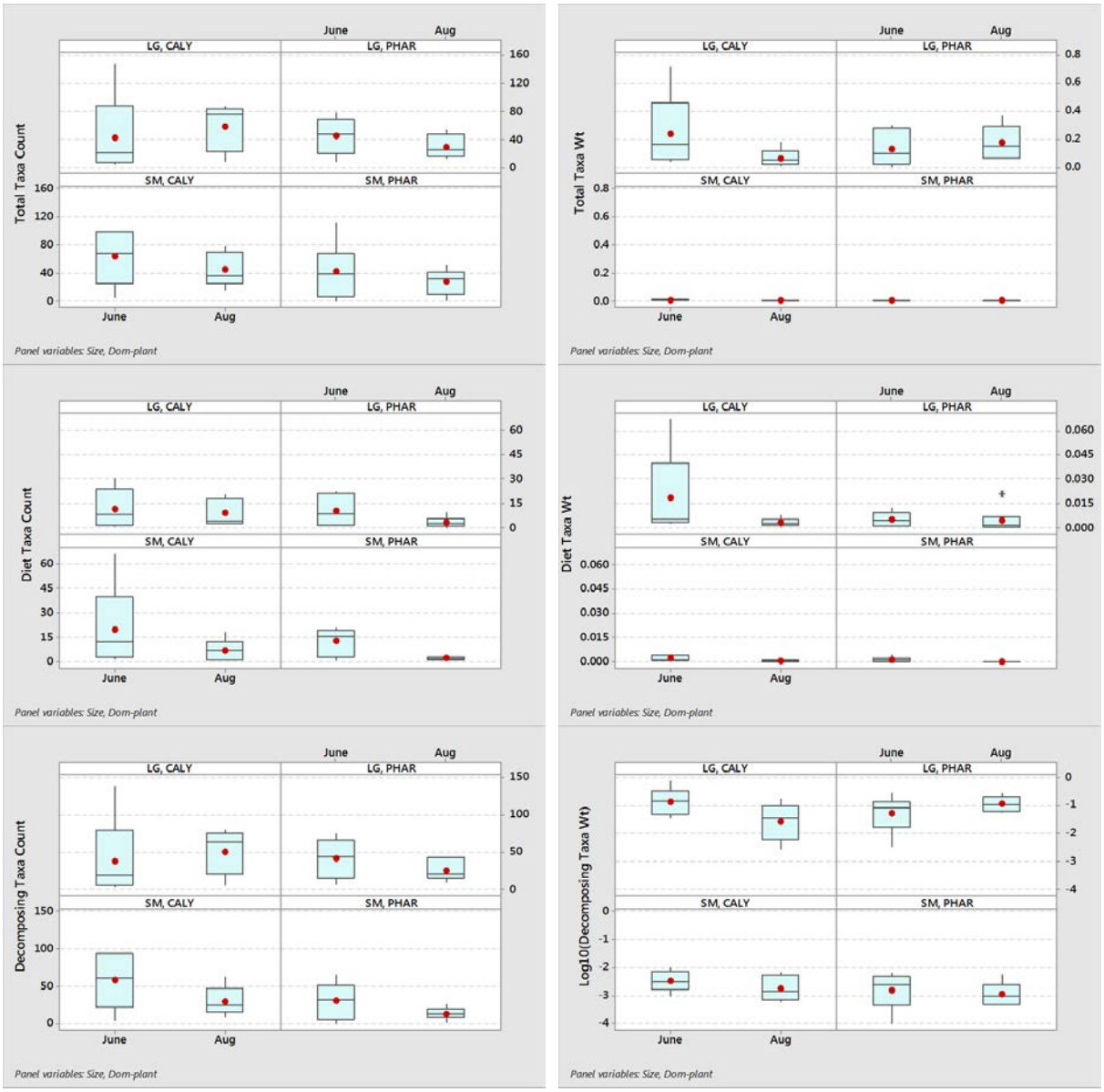


Figure 14. Boxplots of results for the counts (left) and weights (right) of all taxa combined (top panels), the diet taxa (middle panels), and the decomposing taxa (bottom panels) in large and small mesh size litter bags for each plant type after retrieval in June and in August.

3.3.3 Macrodetritus

We assessed the quantity (dry weight) and quality (C:N) of detritus at the sampling sites in April and June to better understand the macrodetrital constituent available to macroinvertebrates,

particularly salmon prey. The dry weight of the macrodetritus collected in situ was not significantly different between *C. lyngbyei* and *P. arundinacea* sites nor between the sample collection times (Figure 15). When macrodetrital dry weight was regressed against the covariates, the percent fines ($p = 0.007$) and river kilometer ($p = 0.040$), both covariates were found to be significant explanatory variables, however neither covariate proved to be a good predictor of the quantity of detrital material present at a site ($R^2 < 29\%$). The C:N of the macrodetritus collected in situ was not significantly different between *C. lyngbyei* and *P. arundinacea* sites nor between the sample collection times (Figure 16a). Variability was high in both types of sampling sites and was especially high in the samples collected in *P. arundinacea* sites in June (Figure 16b). None of the covariates had significant slopes ($p > 0.06$).

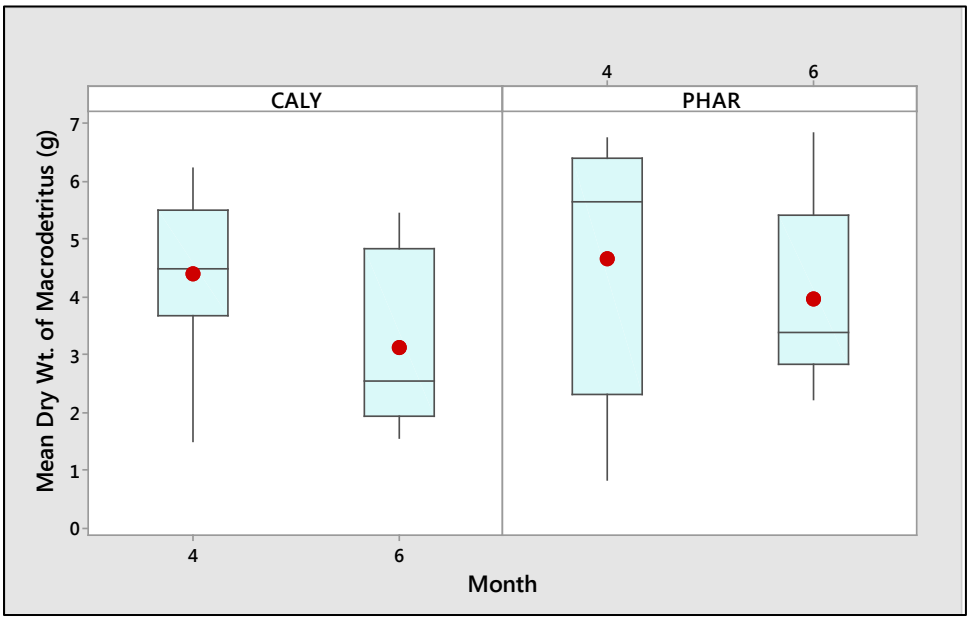
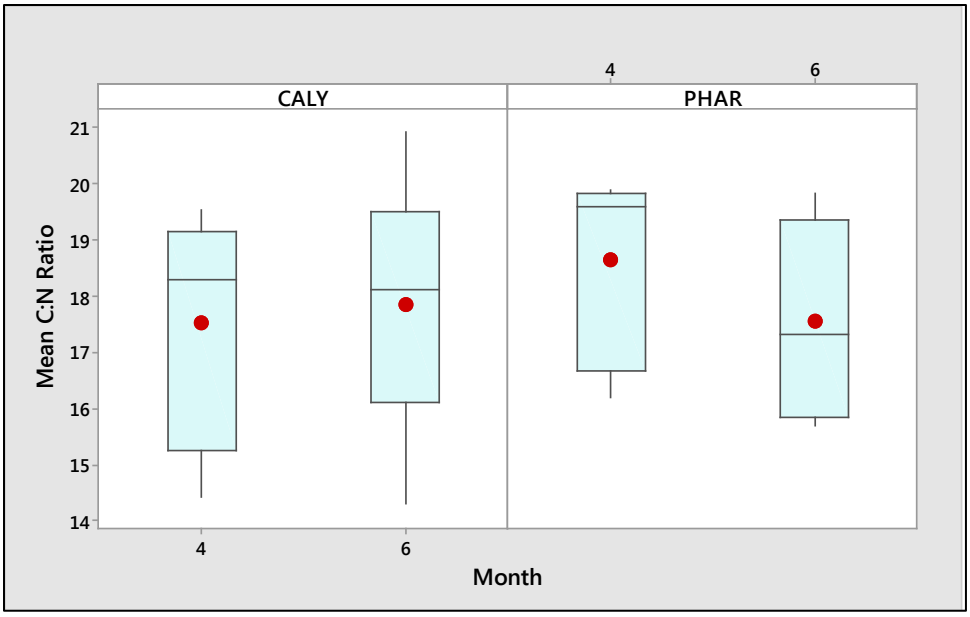


Figure 15. Boxplot of the results of the in situ macrodetritus collection (g dry weight) from the two target vegetation types and for two sample periods (April and June).

a)



b)

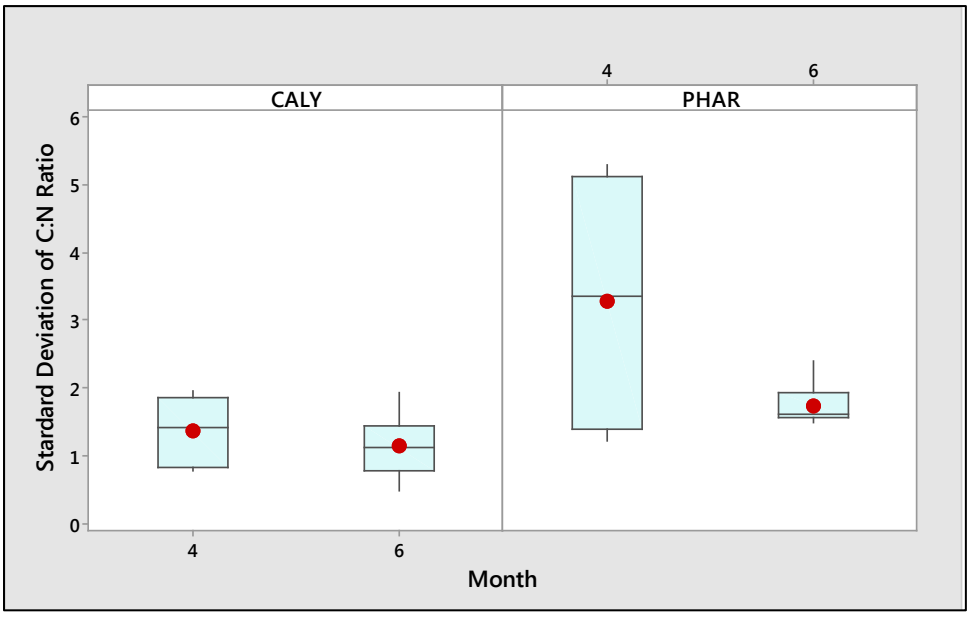


Figure 16. Boxplot of the results of the C:N measured in the in situ macrodetritus samples from the two target vegetation types and for two sample periods (April and June).

3.4 Macroinvertebrates

3.4.1 Fallout Traps

3.4.1.1 ***Abundance***

The average density of all invertebrate taxa combined collected in fallout traps was higher in *P. arundinacea* than in CALY, except in May (Table 8). Overall, average invertebrate density in both types of vegetation increased over time. Effect size estimates (Hedges' *g*) for the square

root of all taxa density between the two vegetation types were small (see Sullivan and Fein 2012). Effect size ranged from 0.26 ± 1.42 in April to 0.39 ± 1.43 in June. However, the range of the confidence interval around the effect size makes it difficult to interpret the magnitude of the effect of vegetation type on invertebrate abundance.

In contrast to the patterns observed for all invertebrate taxa, the average density of all Diptera (including Chironomidae), as well as of Chironomidae, collected in fallout traps was higher in *C. lyngbyei* than in *P. arundinacea* in all months (Table 8). Overall, average density of flies in both types of vegetation increased over time. Effect size estimates for the square root of Diptera and Chironomidae densities between the two vegetation types were generally greater than estimates for all taxa.

The average density of Collembola collected in fallout traps was higher in *P. arundinacea* than in *C. lyngbyei* in all months (Table 8). Average Collembola density was relatively low in earlier sample periods with a considerable increase in June in both types of vegetation. Effect size estimates for the square root of Collembola density between the two vegetation types in May was 0.57 ± 1.44. An estimate was not calculated for April or June because the variance in the data remained unequal after square root transformation, and therefore, the pooled estimate of standard deviation could not be used.

The interaction between Dominant Plant and Month was not significant for abundance measures of any of the taxa groups reported in Table 9 and Figure 17. Percent Fines was a significant or nearly significant covariate for all taxa, Diptera, and Chironomidae ($p < 0.08$). The main effect of Month was significant for all groups ($p = 0.00$). The main effect of Dominant Plant was significant for Chironomidae (CALY > PHAR; $p = 0.027$) and Collembola (PHAR > CALY; $p = 0.042$), and nearly significant for Diptera (CALY > PHAR; $p = 0.062$).

Table 8. Descriptive statistics on fallout trap taxa abundance (#/m^2/hour). The untransformed mean is presented with statistical measures calculated from the square root transformed data. MOE = margin of error for a 95% confidence interval. SD = standard deviation. The critical value for the F-test for equal variance was 7.15.

Month	Type	Mean ± MOE	SD	F-test	Hedges' g ± MOE
Fallout Traps – All Taxa Abundance					
April	CALY	17.23 ± 5.71	0.66	3.34	0.26 ± 1.42
	PHAR	20.40 ± 10.57	1.22		
May	CALY	68.54 ± 47.96	2.79	1.32	0.27 ± 1.42
	PHAR	55.51 ± 42.58	2.43		
June	CALY	122.57 ± 61.63	2.54	4.51	0.39 ± 1.43
	PHAR	183.46 ± 171.92	5.40		
Fallout Traps – Diptera Abundance					
April	CALY	16.01 ± 5.97	0.73	2.41	0.50 ± 1.44
	PHAR	12.84 ± 8.00	1.13		
May	CALY	60.95 ± 46.56	2.84	1.08	0.33 ± 1.42
	PHAR	46.75 ± 44.66	2.73		
June	CALY	85.40 ± 57.54	2.75	1.32	0.73 ± 1.46
	PHAR	51.77 ± 38.32	2.39		
Fallout Traps – Chironomidae Abundance					
April	CALY	15.19 ± 6.28	0.81	1.93	0.48 ± 1.43
	PHAR	12.05 ± 7.75	1.12		
May	CALY	54.94 ± 44.70	2.88	1.08	0.50 ± 1.44
	PHAR	35.50 ± 38.26	2.77		
June	CALY	77.80 ± 54.75	2.81	1.02	0.87 ± 1.49
	PHAR	40.26 ± 39.76	2.78		
Fallout Traps – Collembola Abundance					
April	CALY	0.66 ± 0.44	0.39	14.57	*unequal variance*
	PHAR	6.51 ± 9.50	1.48		
May	CALY	3.19 ± 4.04	1.15	1.70	0.57 ± 1.44
	PHAR	5.62 ± 4.25	0.88		
June	CALY	28.18 ± 22.64	2.38	7.96	*unequal variance*
	PHAR	123.31 ± 174.68	6.72		

Table 9. Results (p-values) of univariate ANOVA tests on fallout trap taxa abundance between *C. lyngbyei* (CALY) and *P. arundinacea* (PHAR). Main effects of Month and Patch Type (Dominant Plant) and the interaction Month x Patch Type were examined. The covariate Percent Fines was also assessed. P-values are evaluated against an error rate of $\alpha = 0.05$.

	Interaction	*Covariate*	*Main Effect*	
Taxa Group	**Dominant Plant x Month**	**Percent Fines**	**Month**	**Dominant Plant**
All Taxa	0.543	0.082	0.000	0.820
Diptera	0.671	0.033	0.000	0.062
Chironomidae	0.520	0.045	0.002	0.027
Collembola	0.321	0.964	0.000	0.042

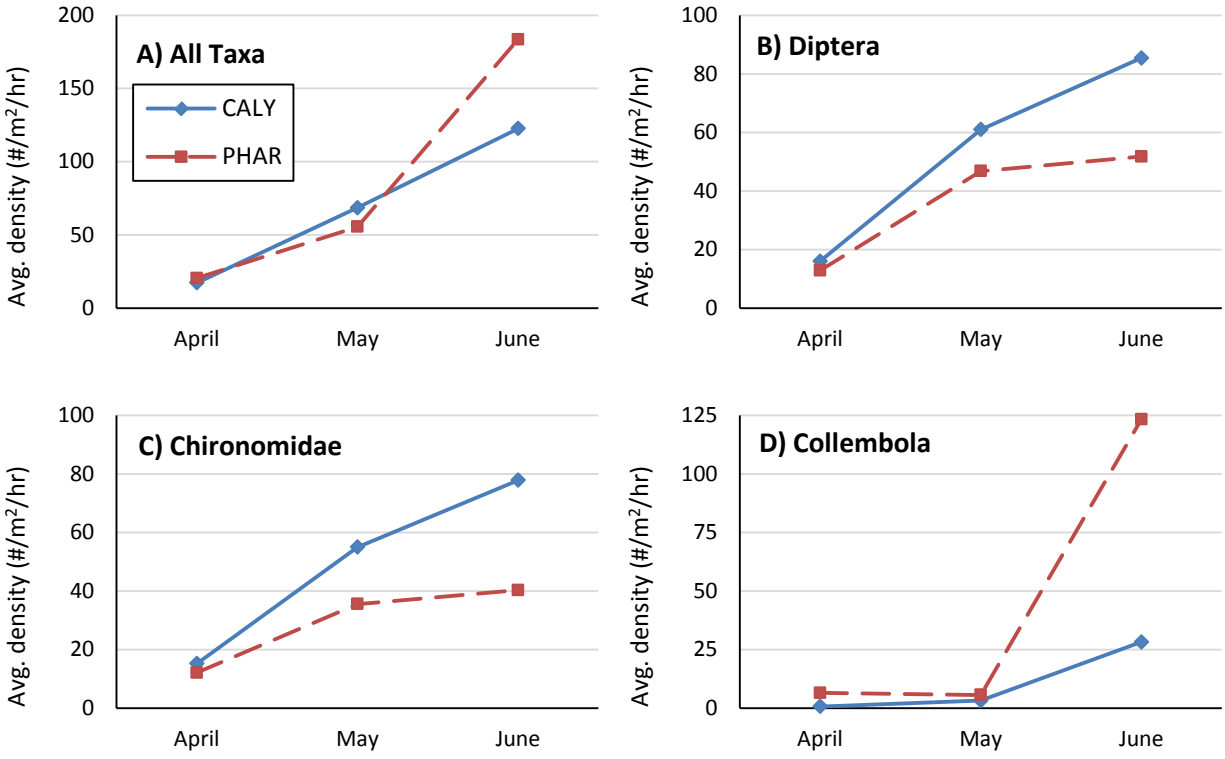


Figure 17. Interaction plots of average density for A) All Taxa, B) Diptera (including Chironomidae), C) Chironomidae, and D) Collembola collected in fallout traps in *C. lyngbyei* (CALY; blue solid line) and *P. arundinacea* (PHAR; red dashed line) during each sampling month.

3.4.1.2 *Biomass*

The average biomass of all invertebrate taxa collected in fallout traps was higher in *P. arundinacea* than in CALY, except in April (Table 10). Overall, invertebrate biomass in both

types of vegetation increased over time. Effect size estimates (Hedges' *g*) for the natural log (+1) of all taxa biomass between the two vegetation types varied by month.

In contrast to the patterns observed for all invertebrate taxa, the average biomass of Diptera (including Chironomidae), as well as of Chironomidae, collected in fallout traps was higher in *C. lyngbyei* than in *P. arundinacea* in all months (Table 10). Diptera and Chironomidae biomass in both types of vegetation peaked in May. Effect size estimates for Diptera biomass between the two vegetation types were greatest in April and estimates were small in both May and June. Effect size estimates for Chironomidae biomass were moderate to large.

The interaction between Dominant Plant and Month was not significant for biomass measures of any of the taxa groups reported in Table 11 and Figure 18. Percent Fines was a significant or nearly significant covariate for analyses for all groups ($p < 0.06$). The main effect of Month was significant for all taxa and Diptera ($p < 0.00$), but not Chironomidae. The main effect of Dominant Plant was significant for Chironomidae (CALY > PHAR; $p = 0.00$), and nearly significant for Diptera (CALY > PHAR; $p = 0.08$).

Table 10. Descriptive statistics on fallout trap taxa biomass (mg/m^2/hour). The untransformed mean is presented with statistical measures on the natural log (+1) transformed data. MOE = margin of error for a 95% confidence interval. SD = standard deviation. The critical value for the F-test for equal variance was 7.15.

Month	Type	Mean ± MOE	SD	F-test	Hedges' *g* ± MOE
Fallout Traps – All Taxa Biomass					
April	CALY	15.19 ± 11.30	0.73	1.79	1.04 ± 1.52
	PHAR	6.17 ± 4.29	0.55		
May	CALY	29.94 ± 21.25	0.64	1.08	0.01 ± 1.41
	PHAR	30.75 ± 27.13	0.67		
June	CALY	56.76 ± 36.33	0.62	2.32	0.22 ± 1.41
	PHAR	89.90 ± 111.20	0.94		
Fallout Traps – Diptera Biomass					
April	CALY	13.72 ± 9.74	0.68	1.06	1.14 ± 1.54
	PHAR	5.37 ± 4.51	0.70		
May	CALY	23.43 ± 19.14	0.77	1.02	0.07 ± 1.41
	PHAR	22.64 ± 22.56	0.76		
June	CALY	21.19 ± 14.06	0.59	1.39	0.06 ± 1.41
	PHAR	19.26 ± 8.82	0.50		
Fallout Traps – Chironomidae Biomass					
April	CALY	6.93 ± 3.10	0.42	3.52	0.87 ± 1.49
	PHAR	4.21 ± 4.31	0.80		
May	CALY	15.03 ± 15.84	0.89	0.79	0.64 ± 1.45
	PHAR	8.53 ± 12.91	1.00		
June	CALY	8.69 ± 5.05	0.58	0.67	0.95 ± 1.50
	PHAR	4.31 ± 3.79	0.71		

Table 11. Results (p-values) of univariate ANOVA tests on fallout trap taxa biomass between *C. lyngbyei* (CALY) and *P. arundinacea* (PHAR). Main effects of Month and Patch Type (Dominant Plant) and the interaction Month x Patch Type were examined. The covariate Percent Fines was also assessed. P-values are evaluated against an error rate of $\alpha = 0.05$.

	Interaction	*Covariate*	*Main Effect*	
Taxa Group	**Dominant Plant x Month**	**Percent Fines**	**Month**	**Dominant Plant**
All Taxa	0.181	0.030	0.000	0.236
Diptera	0.169	0.054	0.002	0.079
Chironomidae	0.994	0.004	0.380	0.002

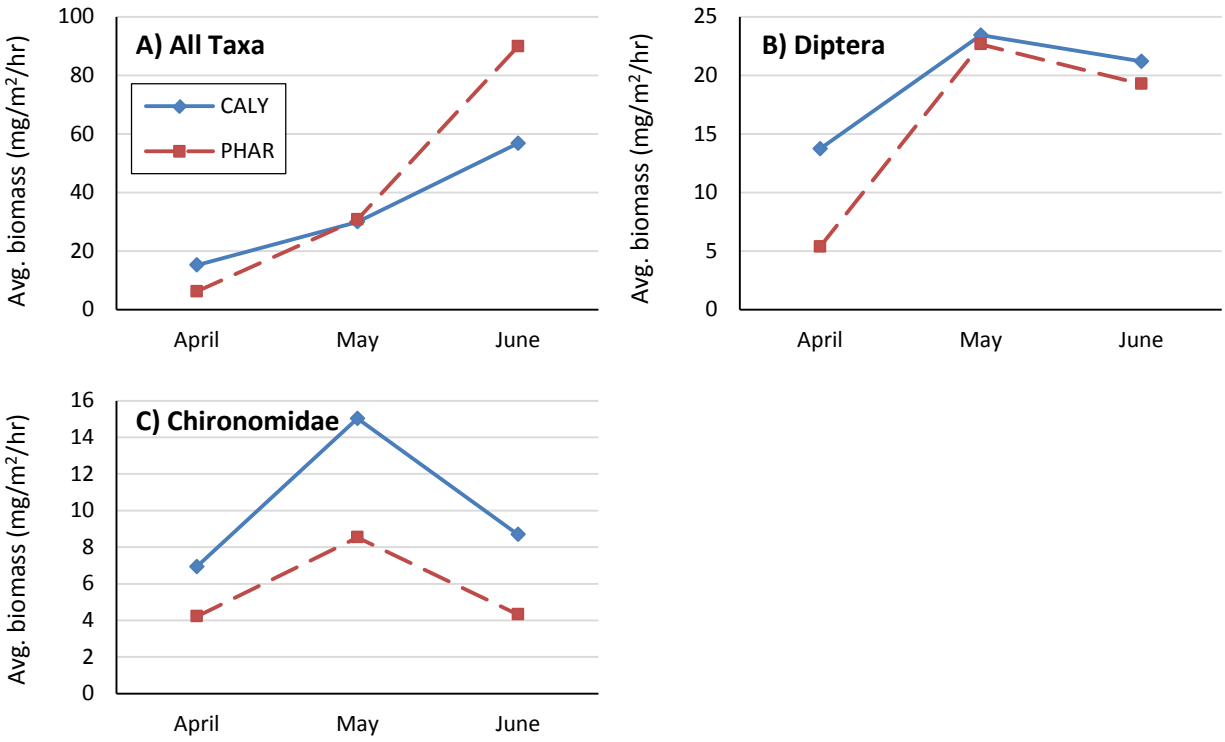


Figure 18. Interaction plots of average biomass for A) All Taxa, B) Diptera (including Chironomidae), and C) Chironomidae collected in fallout traps in *C. lyngbyei* (CALY; blue solid line) and *P. arundinacea* (PHAR; red dashed line) during each sampling month.

3.4.1.3 *Community Composition*

Invertebrate diversity in fallout traps, measured by the Shannon Index (H'), was greater in *P. arundinacea* than in *C. lyngbyei* in all months (Figure 19). The composition of the fallout trap community was generally similar in *C. lyngbyei* and *P. arundinacea* (Figure 20). Major taxa contributing to the fallout assemblage in both vegetation types included flies, Collembola, beetles, and dragonflies. Together, these groups accounted for over 85% of the community composition, in terms of average abundance and biomass. The *C. lyngbyei* community had a

higher average proportional abundance and biomass of Chironomidae than *P. arundinacea* in all months, while *P. arundinacea* had more than twice the average proportional abundance of Collembola compared to *C. lyngbyei* each month (Figure 20).

Overall, the proportional contribution of Chironomidae declined throughout the study period in both *C. lyngbyei* and *P. arundinacea*, and Collembola, beetles, dragonflies, and other fly families (primarily Ephydridae, or shore flies) made a larger contribution to the community composition. Although numerically few beetles and dragonflies were captured in fallout trap samples, the large body size of these insects made a large proportional contribution to average biomass when they were present.

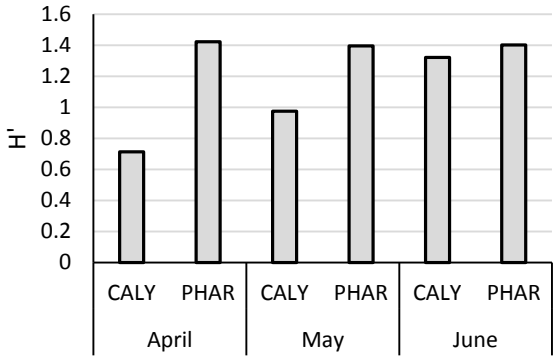


Figure 19. Shannon's Index of diversity (H') of all fallout trap invertebrate taxa.

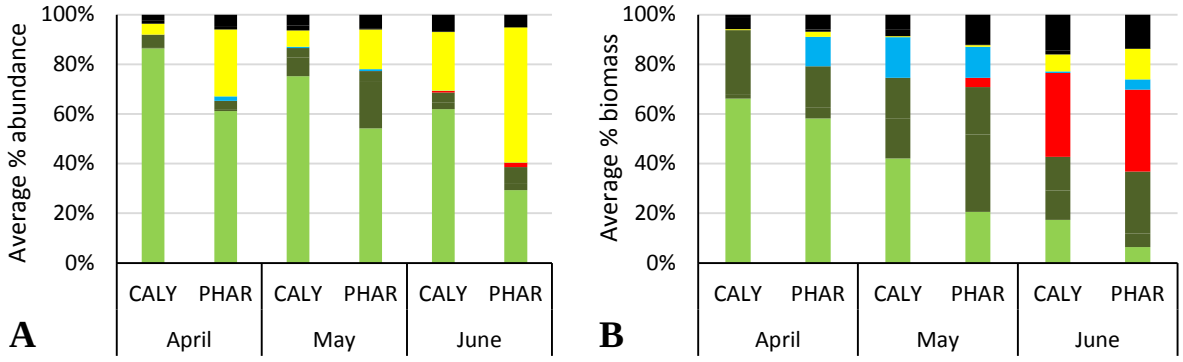


Figure 20. Average composition of fallout traps in *P. arundinacea* (PHAR; n = 6) and *C. lyngbyei* (CALY; n = 6) during each sampling month, by average percent abundance (A) and average percent biomass (B) for each taxonomic group. Light green = Chironomidae (midges), dark green = other Diptera (flies), red = Coenagrionidae (dragonfly), blue = Coleoptera (beetles), yellow = Collembola (springtails), black = other taxa.

All ANOSIM pairwise month comparisons for similarity were significantly different for abundance ($p = 0.00$) and biomass ($p = 0.00$). None of the similarity pairwise comparisons between dominant plant types within month were significantly different (Figure 21; Appendix E).

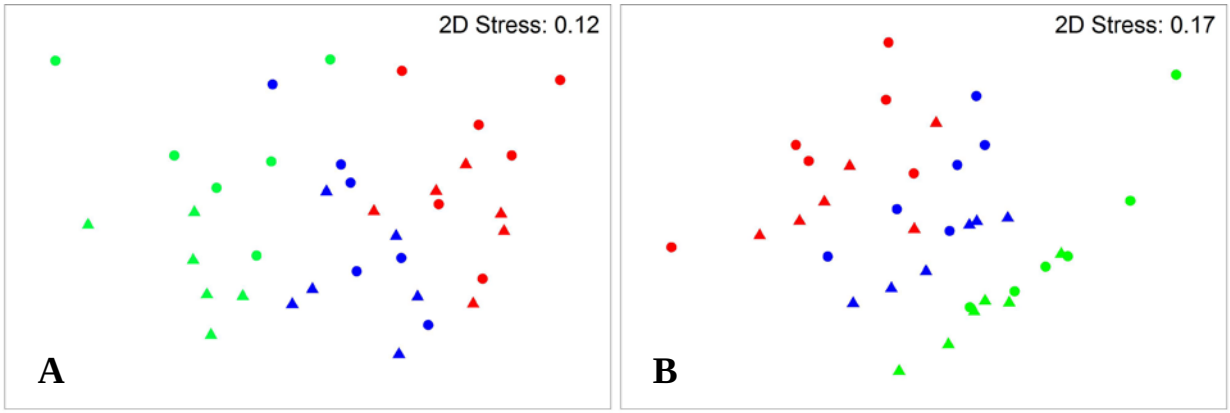


Figure 21. Two-dimensional nMDS ordination plot of *C. lyngbyei* (CALY; triangle Δ) and *P. arundinacea* (PHAR; circle ○) monthly samples of fallout trap taxa abundance (A) and biomass (B). Green = April, blue = May, red = June.

3.4.2 Emergence Traps

3.4.2.1 *Abundance*

The average density of all invertebrate taxa combined that were collected in emergence traps was higher in *P. arundinacea* than in *C. lyngbyei* in all months (Table 12). Overall, average invertebrate density in both types of vegetation increased over time. Effect size estimates (Hedges' *g*) for the square root of all taxa density between the two vegetation types were small, 0.26 ± 1.42 in April and 0.11 ± 1.41 in May. An estimate was not calculated for June because the variance in the data remained unequal after square root transformation, and therefore, the pooled estimate of standard deviation could not be used.

The average density of Diptera (including Chironomidae) collected in emergence traps was similar between *P. arundinacea* and *C. lyngbyei* (Table 12). Overall, average density of flies in both types of vegetation increased over time. Similar to all invertebrate taxa, effect size estimates for the square root of Diptera densities between the two vegetation types were small.

The average density of Chironomidae in emergence traps was higher in *C. lyngbyei* than in *P. arundinacea* in all months and increased over time in both vegetation types (Table 12). Effect size estimates for the square root of Chironomidae densities between the two vegetation types ranged from 0.52 ± 1.44 in April to 0.25 ± 1.42 in June.

The average density of Collembola collected in fallout traps was higher in *P. arundinacea* than in *C. lyngbyei* in all months (Table 12). Consistent with the fallout trap data, average Collembola density was relatively low in early months with a considerable increase in June in both types of vegetation. Effect size estimates for the square root of Collembola density between the two vegetation types were moderate in April and May. An estimate was not calculated for June

because the variance in the data remained unequal after square root transformation, and therefore, the pooled estimate of standard deviation could not be used.

The interaction between Dominant Plant and Month was significant for abundance measures of all taxa and Collembola ($p = 0.00$), therefore invalidating the main effects tests of Dominant Plant and Month (Table 13; Figure 22). Kruskal-Wallis multiple comparisons found that no within month between plant type comparisons was significant for either all taxa or Collembola.

The main effect of Month was significant for Diptera and Chironomidae ($p = 0.00$) (Table 13; Figure 22). The main effect of Dominant Plant was not significant for Diptera or Chironomidae. Percent Fines was not a significant covariate for Diptera or Chironomidae.

Table 12. Descriptive statistics on emergence trap taxa abundance (#/m^2/hour). The untransformed mean is presented with statistical measures calculated from the square root transformed data. MOE = margin of error for a 95% confidence interval. SD = standard deviation. The critical value for the F-test for equal variance was 7.15.

Month	Type	Mean ± MOE	SD	F-test	Hedges' *g* ± MOE
Emergence Traps – All Taxa Abundance					
April	CALY	0.82 ± 0.94	0.42		
	PHAR	0.91 ± 0.63	0.27	2.88	0.26 ± 1.42
May	CALY	3.59 ± 1.48	0.36		
	PHAR	3.87 ± 1.88	0.49	3.55	0.11 ± 1.41
June	CALY	10.08 ± 4.91	0.80		
	PHAR	43.85 ± 29.05	2.47	3.27	*unequal variance*
Emergence Traps – Diptera Abundance					
April	CALY	0.59 ± 0.90	0.44		
	PHAR	0.33 ± 0.22	0.27	2.56	0.35 ± 1.42
May	CALY	2.13 ± 1.05	0.35		
	PHAR	2.13 ± 1.80	0.58	2.79	0.13 ± 1.41
June	CALY	4.09 ± 3.95	0.84		
	PHAR	4.24 ± 1.94	0.47	3.15	0.19 ± 1.41
Emergence Traps – Chironomidae Abundance					
April	CALY	0.57 ± 0.88	0.43		
	PHAR	0.24 ± 0.18	0.24	3.19	0.52 ± 1.44
May	CALY	1.61 ± 1.10	0.40		
	PHAR	1.24 ± 1.39	0.57	2.05	0.43 ± 1.43
June	CALY	3.32 ± 3.93	0.92		
	PHAR	2.24 ± 1.84	0.55	2.82	0.25 ± 1.42
Emergence Traps – Collembola Abundance					
April	CALY	0.16 ± 0.25	0.29		
	PHAR	0.42 ± 0.64	0.38	1.71	0.52 ± 1.44
May	CALY	0.49 ± 0.65	0.42		
	PHAR	0.76 ± 0.49	0.27	2.54	0.44 ± 1.43
June	CALY	3.19 ± 2.28	0.68		
	PHAR	36.67 ± 27.71	2.71	15.78	*unequal variance*

Table 13. Results (p-values) of univariate ANOVA tests on emergence trap taxa abundance between *C. lyngbyei* (CALY) and *P. arundinacea* (PHAR). Main effects of Month and Patch Type (Dominant Plant) and the interaction Month x Patch Type were examined. The covariate Percent Fines was also assessed. P-values are evaluated against an error rate of $\alpha = 0.05$.

	Interaction	*Covariate*	*Main Effect*	
Taxa Group	**Dominant Plant x Month**	**Percent Fines**	**Month**	**Dominant Plant**
All Taxa	0.002	--	--	--
Diptera	0.873	0.347	0.000	0.919
Chironomidae	0.997	0.872	0.001	0.268
Collembola	0.001	--	--	--

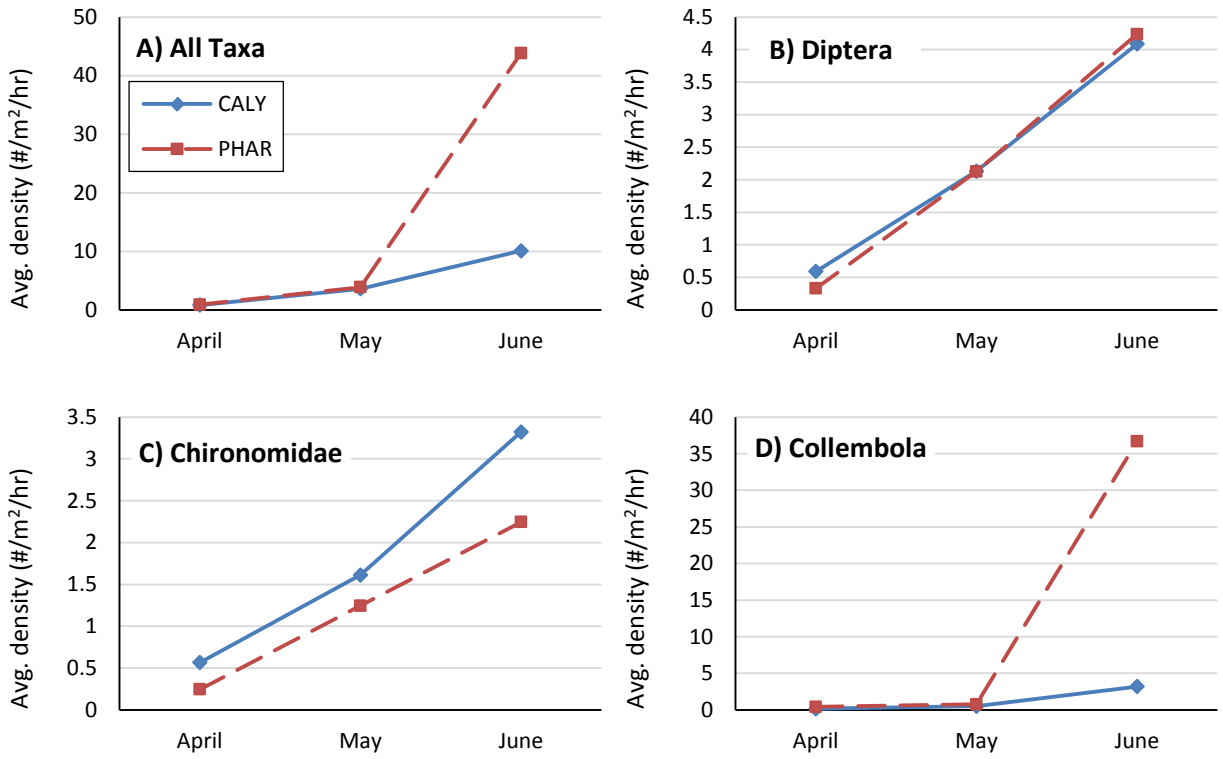


Figure 22. Interaction plots of average density for A) All Taxa, B) Diptera (including Chironomidae), C) Chironomidae, and D) Collembola collected in emergence traps in *C. lyngbyei* (CALY; blue solid line) and *P. arundinacea* (PHAR; red dashed line) during each sampling month.

3.4.2.2 *Biomass*

The average biomass of all invertebrate taxa collected in emergence traps was higher in *P. arundinacea* than in *C. lyngbyei*, except in April (Table 14). Overall, invertebrate biomass in

both types of vegetation increased over time. Effect size estimates (Hedges' *g*) for the natural log (+1) of all taxa biomass between the two vegetation types varied by month.

The average biomass of Diptera (including Chironomidae) was also higher in *P. arundinacea* than in *C. lyngbyei* in all months (Table 14). Diptera biomass in both types of vegetation increased over time. Effect size estimates for the natural log (+1) of Diptera biomass between the two vegetation types ranged from moderate to large. The average biomass of Chironomidae was higher in *C. lyngbyei* than in *P. arundinacea*, except in April; effect size estimates were small across months.

Table 14. Descriptive statistics on emergence trap taxa biomass (mg/m^2/hour). The untransformed mean is presented with statistical measures on the natural log (+1) transformed data. MOE = margin of error for a 95% confidence interval. SD = standard deviation. The critical value for the F-test for equal variance was 7.15.

Month	Type	Mean ± MOE	SD	F-test	Hedges' *g* ± MOE
Emergence Traps – All Taxa Biomass					
April	CALY	0.25 ± 0.49	0.30		
	PHAR	0.24 ± 0.27	0.19	2.54	0.08 ± 1.41
May	CALY	1.10 ± 0.47	0.20		
	PHAR	1.93 ± 1.09	0.35	3.02	0.97 ± 1.51
June	CALY	4.10 ± 3.87	0.63		
	PHAR	4.46 ± 1.90	0.36	3.12	0.36 ± 1.42
Emergence Traps – Diptera Biomass					
April	CALY	0.13 ± 0.19	0.15		
	PHAR	0.20 ± 0.29	0.20	0.53	0.25 ± 1.42
May	CALY	0.75 ± 0.34	0.19		
	PHAR	1.13 ± 0.87	0.38	3.88	0.47 ± 1.43
June	CALY	1.30 ± 1.06	0.43		
	PHAR	2.70 ± 1.92	0.44	0.92	0.99 ± 1.51
Emergence Traps – Chironomidae Biomass					
April	CALY	0.12 ± 0.17	0.13		
	PHAR	0.17 ± 0.07	0.06	6.33	0.28 ± 1.42
May	CALY	0.24 ± 0.16	0.12		
	PHAR	0.20 ± 0.25	0.19	2.47	0.22 ± 1.41
June	CALY	0.18 ± 0.13	0.10		
	PHAR	0.17 ± 0.19	0.14	2.21	0.08 ± 1.41

The interaction between Dominant Plant and Month was not significant for biomass measures of any of the taxa groups reported in Table 15 and Figure 23. Percent Fines was not a significant

covariate for analyses for any group. The main effect of Month was significant for all taxa and Diptera (p = 0.00), but not Chironomidae. The main effect of Dominant Plant was nearly significant for Diptera (PHAR > CALY; p = 0.05), but not significant for all taxa or Chironomidae.

Table 15. Results (p-values) of univariate ANOVA tests on emergence trap taxa biomass between *C. lyngbyei* (CALY) and *P. arundinacea* (PHAR). Main effects of Month and Patch Type (Dominant Plant) and the interaction Month x Patch Type were examined. The covariate Percent Fines was also assessed. P-values are evaluated against an error rate of $\alpha = 0.05$.

	Interaction	*Covariate*	*Main Effect*	
Taxa Group	**Dominant Plant x Month**	**Percent Fines**	**Month**	**Dominant Plant**
All Taxa	0.942	0.327	0.000	0.161
Diptera	0.277	0.209	0.000	0.052
Chironomidae	0.951	0.885	0.184	0.462

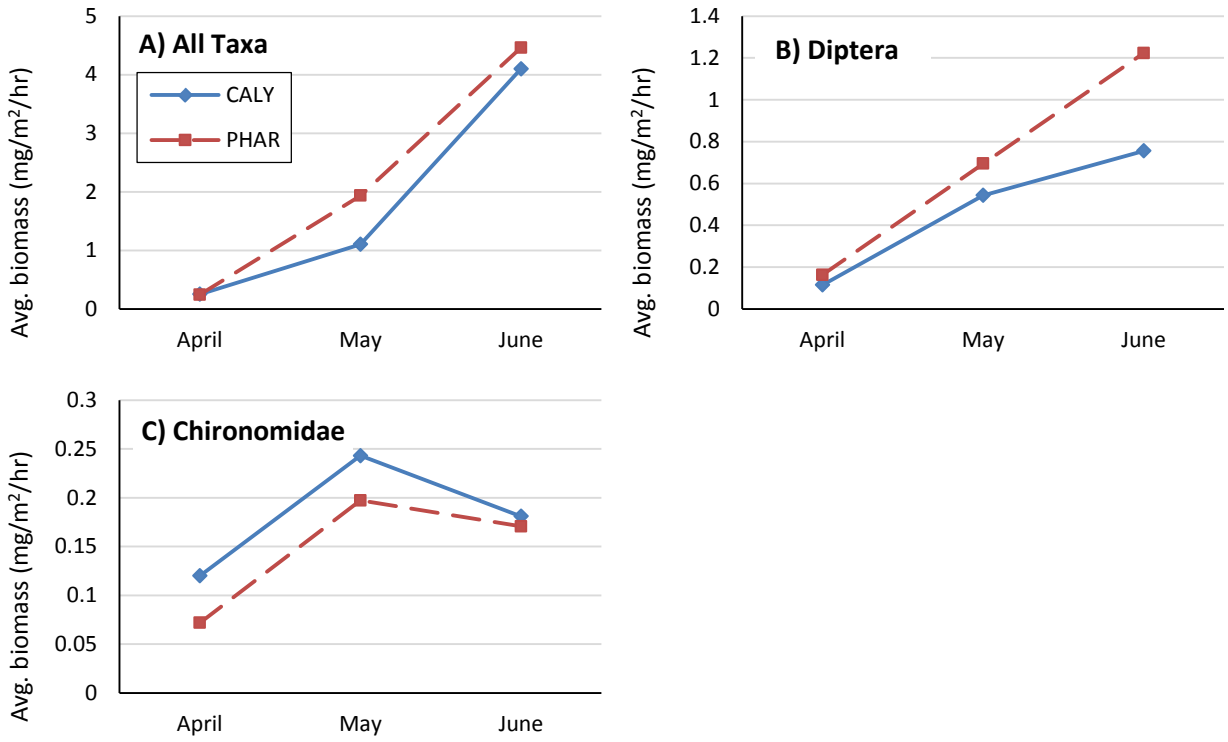


Figure 23. Interaction plots of average biomass for A) All Taxa, B) Diptera (including Chironomidae), and C) Chironomidae collected in emergence traps in *C. lyngbyei* (CALY; blue solid line) and *P. arundinacea* (PHAR; red dashed line) during each sampling month.

3.4.2.3 *Community Composition*

Invertebrate diversity in emergence traps was greater in *P. arundinacea* in April and May, and *C. lyngbyei* in June (Figure 24). The decrease in June diversity in *P. arundinacea* corresponds to a

numerical dominance by Collembola (springtails) resulting in lower taxa evenness. In general, composition of emergence trap assemblages was similar in *C. lyngbyei* and *P. arundinacea* (Figure 25). Major taxa contributing to the emergence assemblages in both vegetation types included spiders, flies, beetles, springtails, and true bugs. Together, these groups accounted for over 85% of the community composition, in terms of average abundance and biomass. The *C. lyngbyei* community had higher proportions of Chironomidae in all months, while *P. arundinacea* had about twice the average proportion of springtails compared to *C. lyngbyei* each month.

Overall, the proportional contribution of Chironomidae declined over the season in both *C. lyngbyei* and *P. arundinacea*, and springtails, beetles, true bugs, and other fly families made larger contributions to the assemblage. Although few beetles and spiders were captured in emergence trap samples, the generally large body size of these taxa made a large proportional contribution to average biomass.

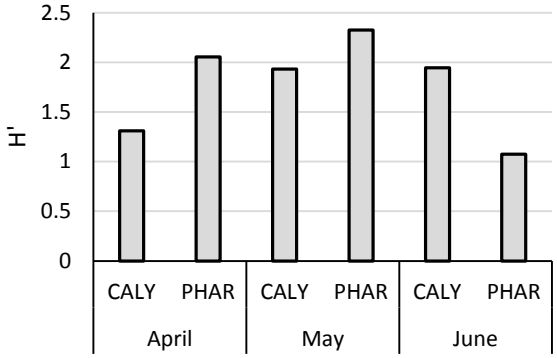


Figure 24. Shannon's Index of diversity (H') of all emergence trap invertebrate taxa.

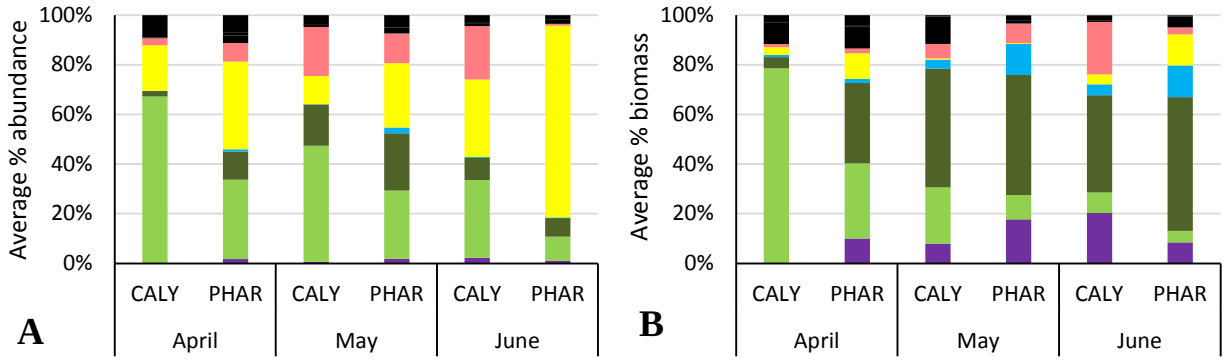


Figure 25. Average composition of emergence traps in *P. arundinacea* (PHAR; n = 6) and *C. lyngbyei* (CALY; n = 6) during each sampling month, by (A) average percent abundance and (B) average percent biomass for each taxonomic group. Purple = Araneae (spiders), light green = Chironomidae (midges), dark green = other Diptera (flies), blue = Coleoptera (beetles), yellow = Collembola (springtails), pink = Hemiptera (true bugs), black = other taxa.

All ANOSIM pairwise month comparisons for similarity are significantly different for abundance and biomass (p = 0.00). No between plant type within month similarity pairwise comparisons were significantly different (Figure 26; Appendix E).

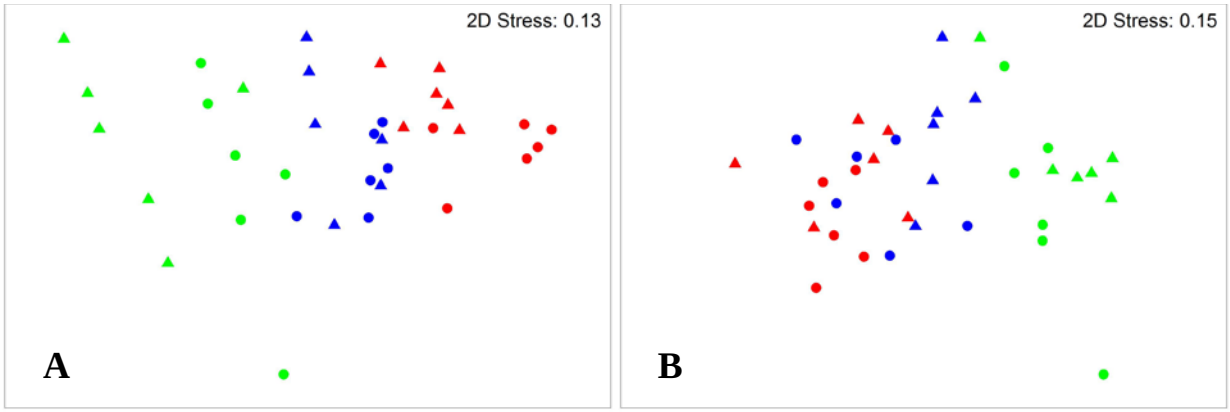


Figure 26. Two-dimensional nMDS ordination plot of *C. lyngbyei* (CALY; triangle Δ) and *P. arundinacea* (PHAR; circle ○) monthly samples of emergence trap taxa abundance (A) and biomass (B). Green = April, blue = May, red = June.

3.4.3 Benthic Cores

3.4.3.1 *Abundance*

The average density (count per core area) of all benthic invertebrate taxa was higher in *C. lyngbyei* than in *P. arundinacea*, except in April (Table 16). Effect size estimates (Hedges' *g*) for the square root of all taxa density between the two vegetation types varied by month.

The average density of Diptera (including Chironomidae) collected in benthic cores was higher in *C. lyngbyei* than in *P. arundinacea* in all months (Table 16). Average density of flies in both types of vegetation was greatest in April and lowest in May. Similar to all invertebrate taxa, effect size estimates for the square root of Diptera densities between the two vegetation types were variable.

Consistent with the fallout and emergence trap data, the average density of Chironomidae in benthic cores was higher in *C. lyngbyei* than in *P. arundinacea* in all months (Table 16). Effect size estimates for the square root of Chironomidae densities between the two vegetation types were variable.

Table 16. Descriptive statistics on benthic invertebrate taxa abundance (count). The untransformed mean is presented with statistical measures calculated from the square root transformed data. MOE = margin of error for a 95% confidence interval. SD = standard deviation. The critical value for the F-test for equal variance was 7.15.

Month	Type	Mean ± MOE	SD	F-test	Hedges' *g* ± MOE
Benthic Cores – All Taxa Abundance					
April	CALY	91.92 ± 38.30	1.83	2.99	0.09 ± 1.41
	PHAR	92.54 ± 58.05	3.16		
May	CALY	101.79 ± 80.03	3.67	4.98	0.74 ± 1.47
	PHAR	54.54 ± 24.41	1.64		
June	CALY	92.63 ± 48.43	2.25	1.62	1.01 ± 1.51
	PHAR	54.41 ± 27.10	1.77		
Benthic Cores – Diptera Abundance					
April	CALY	12.25 ± 7.13	0.93	2.29	0.20 ± 1.41
	PHAR	11.48 ± 8.15	1.40		
May	CALY	10.08 ± 5.18	0.83	1.26	0.81 ± 1.48
	PHAR	6.08 ± 5.11	0.93		
June	CALY	11.67 ± 4.15	0.63	3.08	0.56 ± 1.44
	PHAR	8.97 ± 7.64	1.11		
Benthic Cores – Chironomidae Abundance					
April	CALY	7.13 ± 5.92	0.92	1.35	0.56 ± 1.44
	PHAR	4.68 ± 3.51	1.07		
May	CALY	7.00 ± 3.93	0.80	1.16	0.90 ± 1.49
	PHAR	3.63 ± 3.78	0.87		
June	CALY	5.08 ± 3.37	0.71	1.62	0.18 ± 1.41
	PHAR	4.68 ± 3.33	0.90		

The interaction between Dominant Plant and Month was not significant for abundance measures of any of the taxa groups reported in Table 17 and Figure 27. Percent Fines was a significant or nearly significant covariate for all taxa, Diptera, and Chironomidae ($p < 0.06$). The main effect of Month was not significant for any of the groups. The main effect of Dominant Plant was significant for all taxa (CALY > PHAR; $p = 0.003$), Diptera (CALY > PHAR; $p = 0.041$), and Chironomidae (CALY > PHAR; $p = 0.045$).

Table 17. Results (p-values) of univariate ANOVA tests on benthic core taxa abundance between *C. lyngbyei* (CALY) and *P. arundinacea* (PHAR). Main effects of Month and Patch Type (Dominant Plant) and the interaction Month x Patch Type were examined. The covariate Percent Fines was also assessed. P-values are evaluated against an error rate of $\alpha = 0.05$.

	Interaction	*Covariate*	*Main Effect*	
Taxa Group	**Dominant Plant x Month**	**Percent Fines**	**Month**	**Dominant Plant**
All Taxa	0.316	0.000	0.329	0.003
Diptera	0.781	0.005	0.292	0.041
Chironomidae	0.632	0.056	0.908	0.045

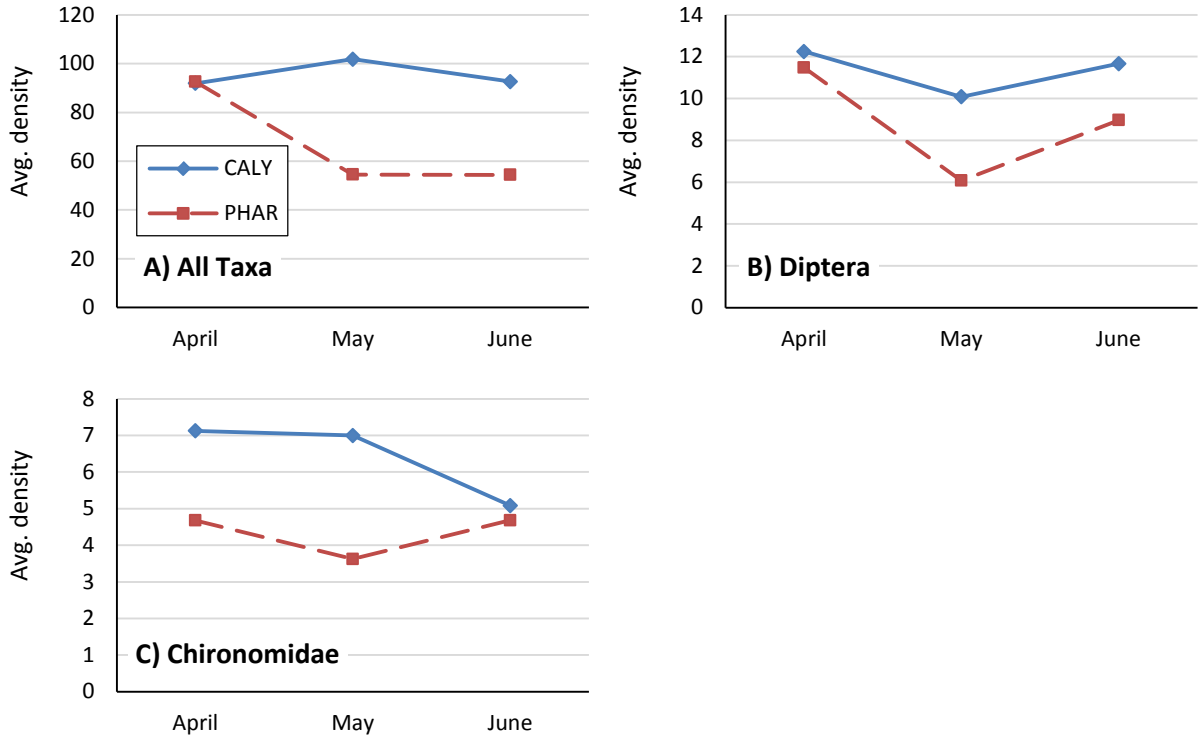


Figure 27. Interaction plots of average density (count) for A) All Taxa, B) Diptera (including Chironomidae), and C) Chironomidae collected in benthic cores in *C. lyngbyei* (CALY; blue solid line) and *P. arundinacea* (PHAR; red dashed line) during each sampling month.

3.4.3.2 *Biomass*

The average biomass of all benthic invertebrate taxa was higher in *P. arundinacea* than in *C. lyngbyei* in all months (Table 18). Effect size estimates (Hedges' *g*) for the natural log (+1) of all taxa biomass between the two vegetation types ranged from very small (0.09 ± 1.41) in April to large (1.01 ± 1.51) in June.

The average biomass of Diptera (including Chironomidae), and of Chironomidae, collected in benthic cores was higher in *C. lyngbyei* than in *P. arundinacea*, except in June (Table 18). Effect

size estimates for the natural log (+1) of monthly Diptera and Chironomidae biomass between the two vegetation types were variable. An estimate was not calculated for June Chironomidae biomass because the variance in the data remained unequal after square root transformation, and therefore, the pooled estimate of standard deviation could not be used.

Table 18. Descriptive statistics on benthic invertebrate taxa biomass (mg). The untransformed mean is presented with statistical measures on the natural log (+1) transformed data. MOE = margin of error for a 95% confidence interval. SD = standard deviation. The critical value for the F-test for equal variance was 7.15.

Month	Type	Mean ± MOE	SD	F-test	Hedges' *g* ± MOE
Benthic Cores – All Taxa Biomass					
April	CALY	94.80 ± 63.67	1.83	2.99	0.09 ± 1.41
	PHAR	99.31 ± 58.90	3.16		
May	CALY	112.00 ± 115.29	3.67	4.98	0.80 ± 1.47
	PHAR	119.23 ± 68.76	1.64		
June	CALY	85.98 ± 81.62	2.25	1.62	1.01 ± 1.51
	PHAR	117.11 ± 48.02	1.77		
Benthic Cores – Diptera Biomass					
April	CALY	4.15 ± 2.51	0.47	0.55	0.03 ± 1.41
	PHAR	2.93 ± 2.25	0.63		
May	CALY	3.05 ± 1.15	0.27	4.08	0.53 ± 1.44
	PHAR	2.53 ± 2.36	0.54		
June	CALY	3.78 ± 2.85	0.51	4.15	0.15 ± 1.41
	PHAR	6.49 ± 7.64	1.05		
Benthic Cores – Chironomidae Biomass					
April	CALY	2.43 ± 2.46	0.53	2.10	0.04 ± 1.41
	PHAR	0.99 ± 0.68	0.37		
May	CALY	1.15 ± 0.54	0.24	2.06	1.07 ± 1.52
	PHAR	0.58 ± 0.58	0.34		
June	CALY	0.35 ± 0.22	0.16	16.00	*unequal variance*
	PHAR	1.39 ± 1.93	0.64		

The interaction between Dominant Plant and Month was not significant for biomass measures of any of the taxa groups reported in Table 19 and Figure 28. Percent Fines was a significant covariate for all taxa ($p = 0.018$). The main effect of Month and Dominant Plant was not significant ($p > 0.30$) for any of the taxa groups.

Table 19. Results (p-values) of univariate ANOVA tests on benthic core taxa biomass between *C. lyngbyei* (CALY) and *P. arundinacea* (PHAR). Main effects of Month and Patch Type (Dominant Plant) and the interaction Month x Patch Type were examined. The covariate Percent Fines was also assessed. P-values are evaluated against an error rate of $\alpha = 0.05$.

	Interaction	*Covariate*	*Main Effect*	
Taxa Group	**Dominant Plant x Month**	**Percent Fines**	**Month**	**Dominant Plant**
All Taxa	0.858	0.018	0.809	0.694
Diptera	0.606	0.216	0.561	0.411
Chironomidae	0.073	0.313	0.198	0.382

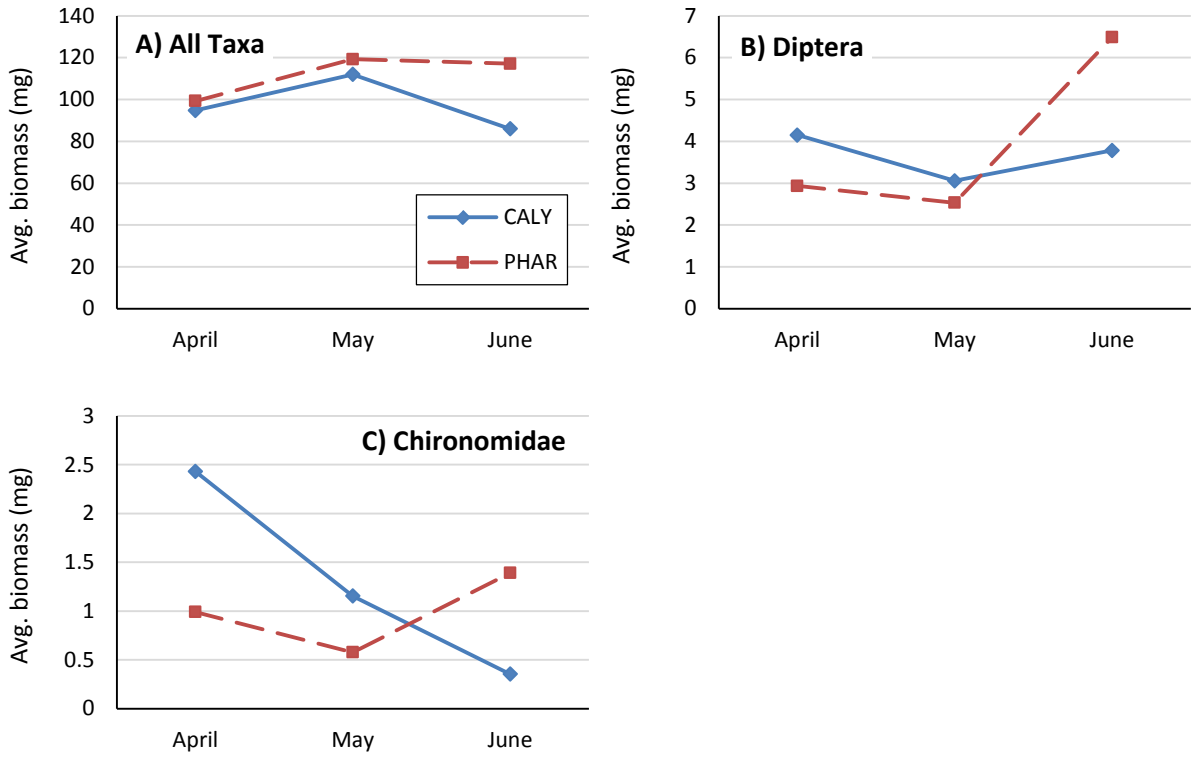


Figure 28. Interaction plots of average biomass (mg) for A) All Taxa, B) Diptera (including Chironomidae), and C) Chironomidae collected in benthic cores in *C. lyngbyei* (CALY; blue solid line) and *P. arundinacea* (PHAR; red dashed line) during each sampling month.

3.4.3.3 *Community Composition*

Invertebrate diversity in benthic cores was similar in the *P. arundinacea* and *C. lyngbyei* in all months (Figure 29). The composition of the benthic community was similar in *C. lyngbyei* and *P. arundinacea* (Figure 30). Major taxa contributing to the benthic assemblage in both vegetation types included flies, springtails, annelid worms, nematode worms, and bivalves. Together, these groups accounted for over 90% of the community composition, in terms of average abundance and biomass.

Composition patterns of the benthic community, including important juvenile Chinook prey taxa, were more apparent when the numerically and gravimetrically dominant annelid and nematode worms were removed (Figure 31). The *C. lyngbyei* community had a higher average proportional abundance and biomass of Chironomidae compared to *P. arundinacea*, except in June. Although few gammarid amphipods and other insects (such as beetles) were collected in benthic core samples, their generally large body size made a large proportional contribution to average biomass.

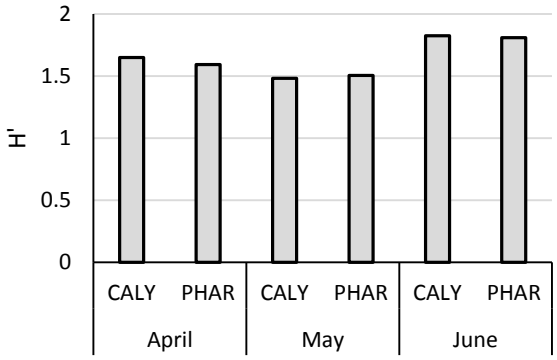


Figure 29. Shannon's Index of diversity (H') of all benthic core invertebrate taxa.

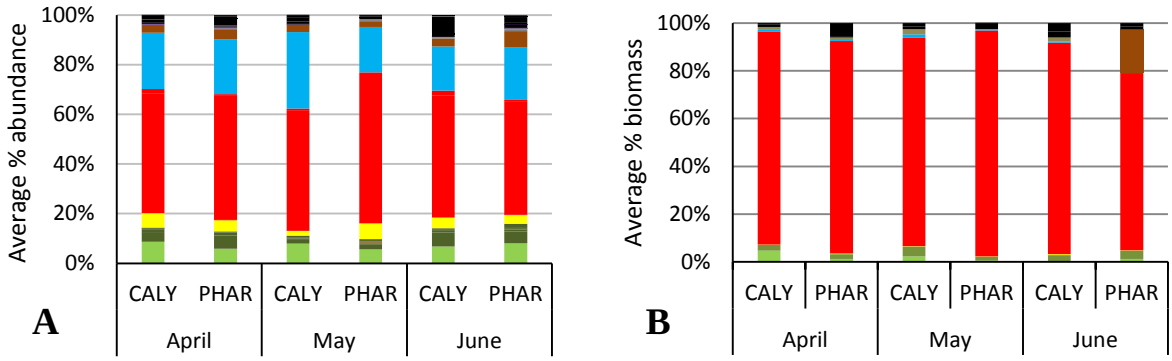


Figure 30. Average composition of benthic cores in *P. arundinacea* (PHAR; n = 6) and *C. lyngbyei* (CALY; n = 6) during each sampling month, by (A) average percent abundance and (B) average percent biomass for each taxonomic group. Light green = Chironomidae (midges), dark green = other Diptera (flies), yellow = Collembola (springtails), red = Annelida (worms), blue = Nematoda (nematode worms), brown = Bivalvia (bivalves), gray = other insect, purple = Gammaridea (gammarid amphipod), black = other taxa.

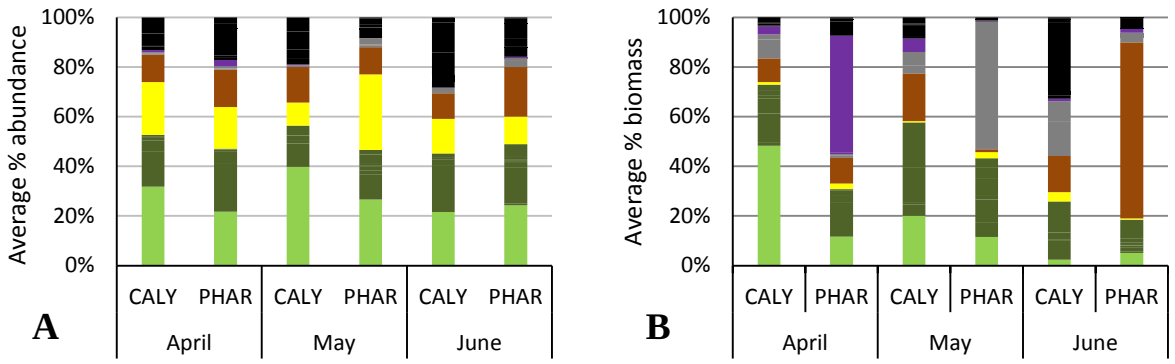


Figure 31. Average composition, not including Annelid or Nematode worms, of benthic cores in *P. arundinacea* (PHAR; n = 6) and *C. lyngbyei* (CALY; n = 6) during each sampling month, by (A) average percent abundance and (B) average percent biomass for each taxonomic group. Light green = Chironomidae (midges), dark green = other Diptera (flies), yellow = Collembola (springtails), brown = Bivalvia (bivalves), gray = other insect, purple = Gammaridea (gammarid amphipod), black = other taxa.

None of the ANOSIM pairwise month comparisons for similarity were significantly different for benthic invertebrate abundance or biomass. No between plant type within month similarity pairwise comparisons were significantly different (Figure 32; Appendix E).

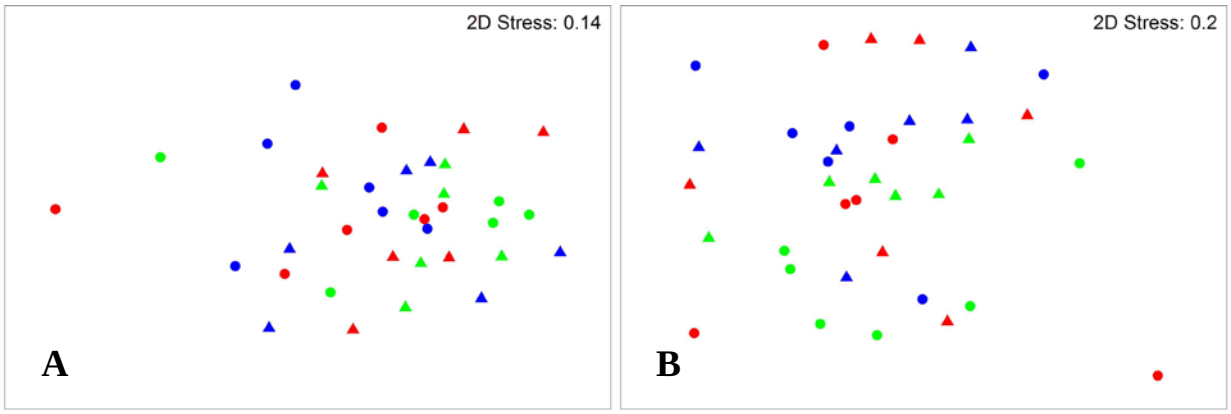


Figure 32. Two-dimensional nMDS ordination plot of *C. lyngbyei* (CALY; triangle Δ) and *P. arundinacea* (PHAR; circle ○) monthly samples of benthic core taxa abundance (A) and biomass (B). Green = April, blue = May, red = June.

3.4.4 Relationship to Vegetation

The area surrounding the sample plots was assessed for plant species composition and aerial cover in August 2014. The density and biomass of macroinvertebrates from all sample methods were regressed against the percent cover of *C. lyngbyei* and *P. arundinacea* surrounding the sample plots. While all the R^2 values were less than 60%, indicating that these regressions were

not useful for predictive purposes, the slope of some regressions were significantly different than 0. Significant regressions between all taxa, Chironomidae, Diptera, and Collembola and cover are highlighted in Table 20 and Table 21. There was a significant positive relationship between Chironomidae (density and biomass) from the fallout traps and *C. lyngbyei* in all months (Table 20; Figure 33). Likewise, a positive relationship was found between *C. lyngbyei* cover and Diptera density from the fallout traps in all months and with Diptera biomass in April (Table 20; Figure 33). A negative relationship between *C. lyngbyei* cover and Collembola density from the fallout traps was observed in April and from the emergent traps in June (Table 20; Figure 33).

Table 20. Results (R-squared) of regression analysis between percent cover of *C. lyngbyei* (CALY) surrounding sample areas and density (square root transformed) and biomass (log transformed) of taxa from benthic cores, emergent traps, and fallout traps. P-values < 0.05 indicate the slope of the regression is significantly different than 0 and are highlighted in yellow. R-squared values >0.5 are bolded.

	April		May		June	
	Density	**Biomass**	**Density**	**Biomass**	**Density**	**Biomass**
All Taxa						
Benthic Cores	0.034	0.050	0.008	0.007	0.296	0.038
p-values	0.564	0.483	0.784	0.791	0.068	0.544
Emergent Traps	0.000	0.000	0.000	0.082	0.388	0.003
p-values	0.951	0.698	0.975	0.367	**0.031**	0.860
Fallout Traps	0.025	0.397	0.361	0.288	0.010	0.122
p-values	0.622	0.028	0.039	0.072	0.752	0.026
Chironomidae						
Benthic Cores	0.071	0.167	0.045	0.222	0.066	0.008
p-values	0.403	0.187	0.507	0.122	0.418	0.776
Emergent Traps	0.053	0.029	0.014	0.033	0.031	0.048
p-values	0.473	0.597	0.717	0.573	0.587	0.494
Fallout Traps	0.415	**0.595**	0.447	**0.533**	0.423	0.461
p-values	0.024	0.003	0.018	0.007	0.022	0.015
Diptera						
Benthic Cores	0.023	0.127	0.026	0.008	0.229	0.003
p-values	0.6392	0.2554	0.613	0.784	0.115	0.875
Emergent Traps	0.0361	0.076	0.001	0.005	0.012	0.192
p-values	0.5543	0.384	0.940	0.822	0.732	0.154
Fallout Traps	0.455	0.466	0.391	0.292	0.364	0.000
p-values	0.016	0.014	0.030	0.070	0.038	0.961
Collembola						
Emergent Traps	0.016	NA	0.318	NA	**0.522**	NA
p-values	0.696	NA	0.056	NA	0.008	NA
Fallout Traps	0.415	NA	0.232	NA	0.222	NA
p-values	0.024	NA	0.113	NA	0.122	NA

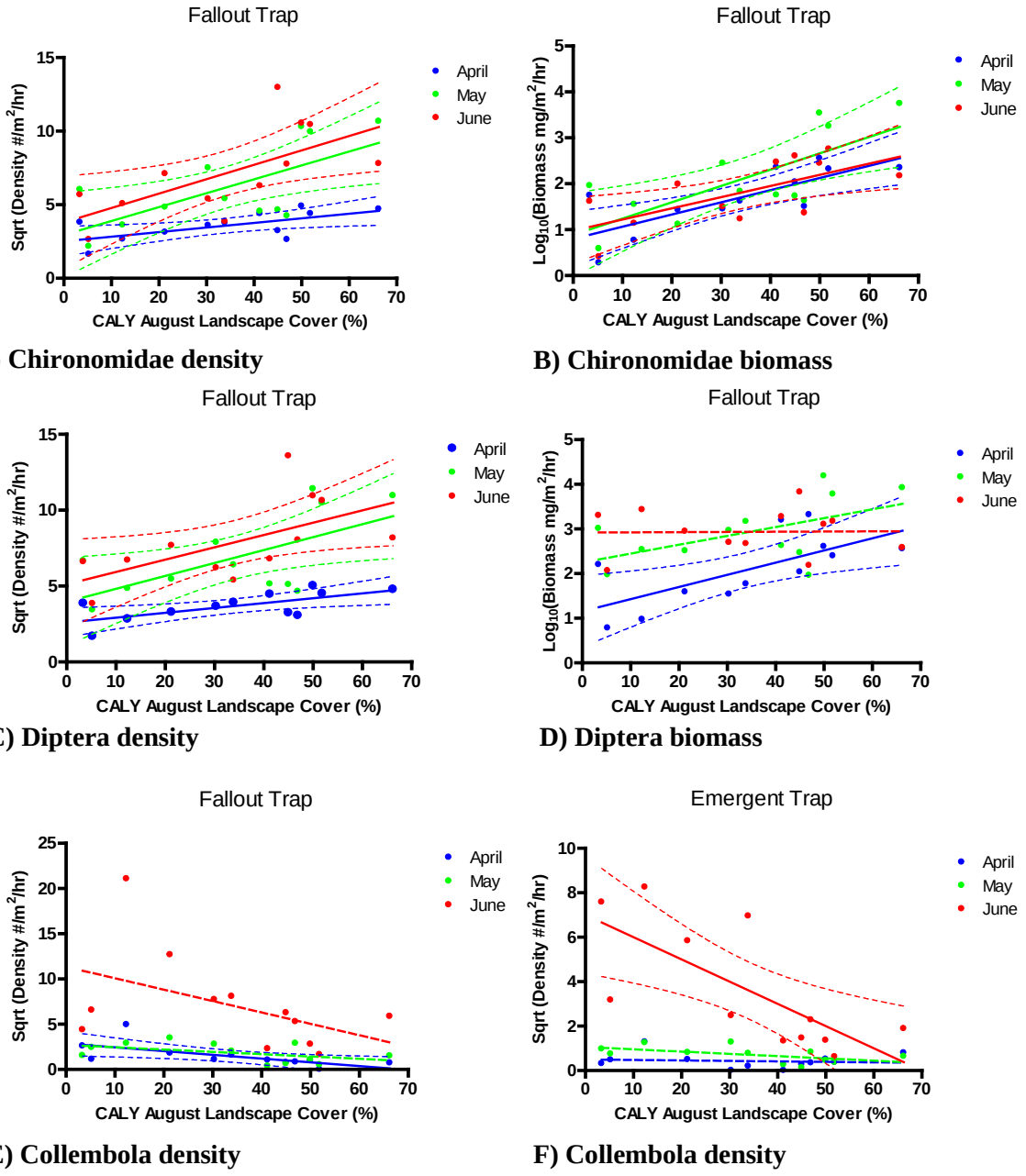


Figure 33. Macroinvertebrate abundance (density) and biomass data regressed against August *C. lyngbyei* (CALY) cover in the landscape surrounding and including the sample plots. Data are from fallout traps for Chironomidae (A and B), Diptera (C and D), and Collembola (E) and from emergent traps for Collembola (F). Regression lines that are significantly different than 0 ($p > 0.05$) are shown as a solid line with 95% confidence limits; all other regression lines are shown as a dashed line.

There was a significant negative relationship between landscape scale *P. arundinacea* cover and the density of all taxa in the June benthic cores. A negative relationship was also found between *P. arundinacea* and Chironomidae density and biomass from the benthic cores in May, from Chironomidae density in fallout traps in April, and Chironomidae biomass from the fallout traps in all months (Table 21). Likewise, a negative relationship was found between *P. arundinacea* cover and Diptera density in the benthic cores in May and with Diptera density and biomass from the fallout traps in April (Table 21). No significant results were found between landscape scale *P. arundinacea* cover and Collembola density in any trap type in any month.

Table 21. Results (R-squared) of regression analysis between percent cover of *P. arundinacea* (PHAR) surrounding sample areas and the density (square root transformed) and biomass (log transformed) of taxa from benthic cores, emergent traps, and fallout traps. P-values < 0.05 indicate the slope of the regression is significantly different than 0 and are highlighted in yellow; R-squared values >0.5 are bolded.

	April		May		June	
	Density	**Biomass**	**Density**	**Biomass**	**Density**	**Biomass**
All Taxa						
Benthic Cores	0.183	0.068	0.211	0.003	**0.518**	0.210
p-values	0.165	0.415	0.133	0.872	0.008	0.657
Emergent Traps	0.083	0.012	0.116	0.101	0.240	<0.001
p-values	0.362	0.738	0.278	0.314	0.106	0.952
Fallout Traps	0.056	0.270	0.189	0.095	0.028	0.058
p-values	0.459	0.084	0.158	0.329	0.601	0.450
Chironomidae						
Benthic Cores	0.171	0.163	0.486	0.499	0.105	0.011
p-values	0.182	0.194	0.012	0.010	0.305	0.743
Emergent Traps	0.072	0.008	0.321	0.238	0.009	0.004
p-values	0.400	0.785	0.055	0.108	0.774	0.836
Fallout Traps	0.474	**0.588**	0.315	0.376	0.271	**0.531**
p-values	0.013	0.004	0.058	0.034	0.083	0.007
Diptera						
Benthic Cores	0.106	0.220	0.453	0.229	0.306	0.019
p-values	0.302	0.124	0.016	0.116	0.062	0.668
Emergent Traps	0.047	0.008	0.206	0.003	0.012	0.123
p-values	0.498	0.779	0.139	0.861	0.736	0.264
Fallout Traps	0.475	0.406	0.231	0.171	0.224	0.105
p-values	0.013	0.026	0.114	0.182	0.120	0.305
Collembola						
Emergent Traps	0.189	NA	0.114	NA	0.309	NA
p-values	0.158	NA	0.284	NA	0.061	NA
Fallout Traps	0.222	NA	0.266	NA	0.196	NA
p-values	0.122	NA	0.086	NA	0.150	NA

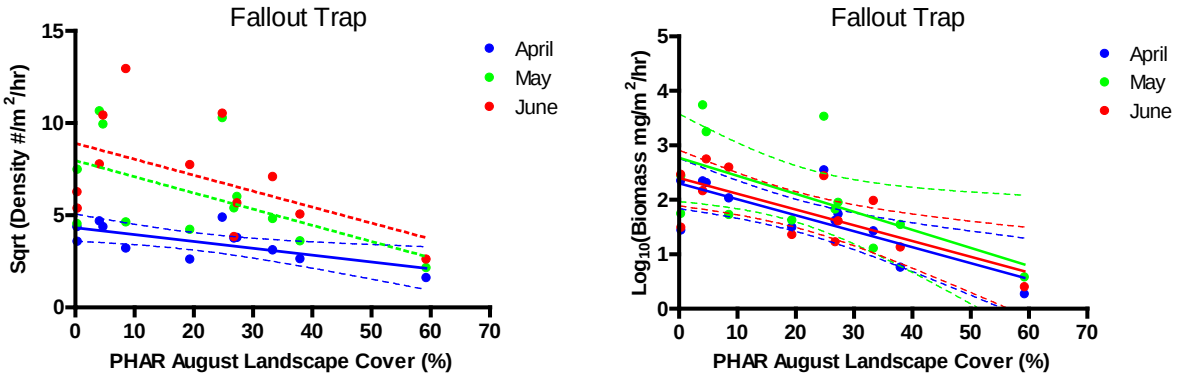


Figure 34. Chironomidae abundance (density) and biomass fallout trap data regressed against August *P. arundinacea* (PHAR) cover in the landscape surrounding and including the sample plots. Data were square root transformed for density (left) and log transformed for biomass (right) for all months. Regression lines that are significantly different than 0 ($p > 0.05$) are shown as a solid line with 95% confidence limits; all other regression lines are shown as a dashed line.

4 Discussion

4.1 Environmental Controlling Factors

The environmental controlling factors that likely play a role in the results of the study include substrate type, substrate organic content, and inundation. Due to the limited number of sample sites that met our criteria for elevation and vegetation homogeneity, we were not able to limit our sampling to a single substrate type; consequently four of the sites were characterized by high sand content and low TOC while the rest of the sites had higher fine sediment and organic content. Grain size and TOC were highly correlated, so percent of fine sediment was used to represent the sediment texture and organic content and was found to be an explanatory variable for several of the macrodetritus and macroinvertebrate metrics, indicating that some of the variability could be explained by this factor. Since it was identified as a covariate, we removed it from our analyses; however future studies should consider sediment characteristics as a site selection criterion.

Wetland inundation is a function of elevation and location in the tidal fluvial continuum (Jay et. al. in review). We attempted to control for variation in inundation within our study as much as possible by limiting the study area to a part of the river that has similar hydrology and by limiting the elevation range at which the sample areas were located, however some variation still existed. Inundation calculated as part of this study was lowest at the highest elevation and most down river site (i.e., CALY2). The site was inundated 24% of the time in June; whereas at the most up river site (i.e., PHAR6) inundation was double that in the same month. The effect of inundation on plant cover and above ground biomass production has been shown in other studies (Hanson et al. 2015; Sagar et al. 2015). However, in this study inundation was not a covariate with the vegetation biomass or decomposition metrics. Although the effect of inundation variability on macroinvertebrate abundance and biomass was not analyzed, river location and elevation were included and neither of these was identified as a covariate.

4.2 Vegetation and Macrodetritus

Study sites were located at the upper end of the elevation and riverine range for *C. lyngbyei* and at the lower end of the elevation and riverine range for *P. arundinacea*. This mixing zone allowed us to compare the two species within similar hydrogeomorphic settings, however there were few large patches dominated by the target vegetation. Additionally, sites were often in close proximity to each other resulting in a mixing of the detrital constituents from the two vegetation species. This situation is very different than that of wetlands located farther up river. In our study, *C. lyngbyei* was a strong competitor (present at all *P. arundinacea* sites), however it does not occur above approximately rkm 90 and no other species seems to have this competitive advantage in the high marshes of the upper river.

Standing Stock and Macrodetritus

Overall, summer peak vegetation biomass was similar between habitats dominated by *C. lyngbyei* and *P. arundinacea*. While *C. lyngbyei* biomass was slightly higher in summer and lower in winter than *P. arundinacea*, these results were not significant due to the high variability in the standing stock. The variability in the above ground biomass is likely a result of the location of the study sites at the outer ends of the species ranges, particularly *P. arundinacea* which did not appear to have a strong competitive advantage over *C. lyngbyei* at these locations. In areas where *P. arundinacea* is more dominant the difference between the species in summer and winter would likely be more pronounced. In fact, this pattern has been observed in long term monitoring data collected throughout the lower river, where *P. arundinacea* was documented to have reduced winter break down and subsequently lower detrital contribution than *C. lyngbyei* (Hanson et al. 2015). In the present study the ratio of winter standing stock to summer standing stock was significantly higher in *P. arundinacea* compared to *C. lyngbyei* indicating that even in this mixing zone the difference between the species was observable. Later in the spring, the standing dead *P. arundinacea* was 12.5 percent, while the standing dead *C. lyngbyei* was only 3.5 percent, further corroborating the finding that *P. arundinacea* does not break down as quickly as *C. lyngbyei*.

Other studies have documented the potential contribution of organic material to the detrital pool. Small et al. (1990) estimate that 38 percent of emergent plant carbon from marshes of the lower estuary of the Columbia River was translocated to the roots and 47 percent entered the detrital pool; many of the marshes were dominated by *C. lyngbyei*. Detailed observations regarding the cycle of living versus dead standing stock of *C. lyngbyei* from a tidal marsh in the Fraser River (Kistritz et al. 1983) indicate that 38% of tissue losses occur due to translocation to the roots in the fall, 37 percent breaks away from the plant in the winter, and 25 percent are buried by sediment in the spring. In both studies a large percentage of the carbon produced by *C. lyngbyei* became a part of the detrital pool within a year.

The in situ macrodetritus collected at the sampling sites decreased from April to June, although not significantly, and it was highly variable at the *P. arundinacea* sites. Cover estimates of detritus at the *C. lyngbyei* study sites also decreased from April to June; however, detritus cover increased over time at the *P. arundinacea* sites. This may be due to movement of detrital material out of the wetlands dominated by *C. lyngbyei* by tidal and hydrological processes and transport of detritus into other areas, including *P. arundinacea* dominated sites (we routinely observed *C. lyngbyei* detritus at *P. arundinacea* sites). In fact, 32 percent of the in situ macrodetritus samples from *P. arundinacea* sites were noted to contain *C. lyngbyei*, while only 13 percent of the *C. lyngbyei* samples contained *P. arundinacea*. This may have resulted in the high variability in C:N ratios from in situ macrodetritus samples collected from *P. arundinacea*. Although, some of this variability could also be due to samples containing *P. arundinacea* stems and one sample containing wood chips. The higher cover of detritus at the *P. arundinacea* sites

in June compared to *C. lyngbyei* sites could also be due to the difference in the timing of the *P. arundinacea* break down, resulting in more detritus in June rather than earlier in the spring.

Decay Rates

Factors that can affect the decay rate of organic material can be categorized as intrinsic and extrinsic controls. For this study we attempted to keep the extrinsic controls, such as inundation, temperature, and nutrient concentration consistent between all sample sites by locating them within a 20 km stretch of the river and at similar elevations. Thus, our focus was to evaluate whether the intrinsic factors within each plant species may cause differences in the rates of organic matter decomposition. Our findings indicate that the decay rate of *C. lyngbyei* was higher than *P. arundinacea*. We hypothesize that this may in part be due to the difference in the amount of stem material present in the two plants, with *P. arundinacea* having a higher proportion of stems in the whole plant and subsequently in the litter samples. Stems and leaf veins typically have higher lignin content, a complex carbon compound that provides structure to plant tissue. While the present study did not measure lignin specifically, the higher carbon content in the *P. arundinacea* litter is indicative of higher lignin content (Aysu 2012). Hobbie (1996) evaluated decomposition rates of stems, leaves, and roots separately for seven species, including two sedge species, and found that decomposition rates were negatively related to carbon quality (lignin and carbohydrate concentrations) and that stems and leaves decomposed differentially. Generally, stems decomposed slower than leaves, except the sedge stems that decayed the fastest. Overall, the two sedge species in the study decomposed more rapidly than the woody and moss species.

In herbaceous species lignin concentration alone is not necessarily related to lower decomposition rates, rather the ratio of lignin to nitrogen is more indicative of the decay rate (Aerts and de Caluwe 1997). Griffiths et al. (2012) evaluated decomposition rates of maize and two grasses, *P. arundinacea* and *Leersia oryzoides* (a native Columbia River grass), and found that differences in rates of decomposition were related to nitrogen and lignin content of the leaves. The lowest decomposition rates occurred in *P. arundinacea* where nitrogen was low (1.3%) and lignin content was high (9%). Multiple studies have found a strong negative relationship between the initial lignin to nitrogen ratio and the resulting decay rate (e.g., Hobbie 1996; Griffiths et al. 2012).

Nitrogen concentrations in both the environment and in organic detritus play a role in decomposition rates because microbes require nitrogen to grow. Organic detritus with a C:N ratio greater than 20:1 is considered N poor relative to microbial demands and can result in incomplete decomposition and no release of N to the environment (Findlay 2013). Our results indicate that the initial levels of N in the litter bags may indeed have been low; the initial C:N ratio was 27.5 and 70.5 for *C. lyngbyei* and *P. arundinacea*, respectively. Over time the ratio decreased in both species and by August the *C. lyngbyei* ratio was 18.8 and 19.8 in the large and small bags, respectively, while the *P. arundinacea* in August was 26.3 and 31.2 in the large and small bags, respectively. The ratios indicate that while the N levels increased in both species over time, the levels in *C. lyngbyei* were much higher in April and by August were contributing

adequate levels of N to the microbe pool and potentially resulting in the faster decay rates observed in *C. lyngbyei* compared to *P. arundinacea* in the small mesh bags in August. In fact, there was a higher number of decomposers found in the litter bags of *C. lyngbyei* than in those of *P. arundinacea* in the small mesh bags in August ($p = 0.045$).

The large decrease in the C:N over time in *P. arundinacea* was likely due to the fact that the *P. arundinacea* material was collected from upright plants that had not come in contact with soil decomposers, while the *C. lyngbyei* material was taken from plants that were partially or completely prostrate. When the litter bags were deployed, the litter was put in direct contact with the soil and therefore the initial changes in N in the *P. arundinacea* samples may be due to this initial contact with soil and decomposing processes. While this is an artifact of our litter collection techniques, it is also likely representative of what happens in a natural setting because *P. arundinacea* is much more likely to remain above the soil surface than *C. lyngbyei* due to the more robust structure of the plant.

4.3 Macroinvertebrates

The macroinvertebrate community composition in fallout and emergence traps showed distinct seasonal shifts with increases in density over time. This pattern is typical, as most insects in temperate regions have life cycles in which they are dormant over the winter and then develop and emerge seasonally, with adult emergence peaking in the early summer (Baxter et al. 2005, Triplehorn and Johnson 2005). Month-to-month variation in insect densities may also be related to environmental conditions during or prior to sampling. Weather factors such as air temperature, wind, and rainfall can influence flight behaviors and the density of insects in traps (e.g., Briers et al. 2003, Williams 1961). Rainy and stormy weather during the sampling events in April 2014 may have depressed insect densities that month. In addition, sampling commenced earlier in the season, before the anticipated peak insect emergence and may have potentially contributed to the low insect densities observed in April. Overall, the proportion of Chironomidae declined over time (from April to June) in patches of both *C. lyngbyei* and *P. arundinacea*, while Collembola (springtails), beetles, dragonflies, and other fly families made a larger contribution to the community composition later in the study period.

When all invertebrate taxa were considered, density and biomass in *P. arundinacea* and *C. lyngbyei* sites were similar for all three trap types, except for densities of invertebrates collected in benthic cores, which were on average higher in *C. lyngbyei* than in *P. arundinacea* ($p = 0.003$; Table 22). Average benthic biomass was higher in *P. arundinacea* than in *C. lyngbyei*, but the margin of error was large (Table 18). The average density and biomass of all taxa combined was generally higher (although not significantly) in *P. arundinacea* than in *C. lyngbyei* in both fallout and emergence traps (Sections 3.4.1 and 3.4.2). In contrast, a number of differences in density and biomass between *C. lyngbyei* and *P. arundinacea* dominated sites were evident for sub-groups of salmon prey that we examined. For combined dipteran flies collected as adults (fallout traps) and as immature forms (benthic cores), densities and biomass were greater in *C. lyngbyei* than in *P. arundinacea* (Table 22). Conversely, average densities and biomass of Diptera

collected in emergence traps were higher in the *P. arundinacea* vegetation than in *C. lyngbyei*. Chironomidae comprise the dominant prey for juvenile Chinook salmon in the lower Columbia River (Lott 2004; Spilseth and Simenstad 2011; Sagar et al. 2013), and for this group, average density and biomass values were greater in fallout traps collected in *C. lyngbyei* compared to those collected in *P. arundinacea* ($p < 0.03$). Also, effect size estimates of Chironomidae density and biomass between the two vegetation types were moderate to large across months (see Sullivan and Fein 2012 for a discussion on the importance of considering effect size). Average abundances of chironomid larvae in benthic cores were also more abundant in *C. lyngbyei* than in *P. arundinacea* ($p = 0.045$). Average density and biomass of Chironomidae collected in emergence traps were consistently greater in *C. lyngbyei* than in *P. arundinacea*, but effect size estimates were generally small to moderate and the mean difference was not significant. Mean Collembola abundances from fallout and emergence traps were greater in *P. arundinacea* than in *C. lyngbyei*, with large increases in density in June, particularly at the *P. arundinacea* dominated sites.

Table 22. Summary of results (p-values) from ANOVA tests of the main effect of vegetation type (dominant plant) on taxa abundance and biomass from the three sample methods. Where the result is significant ($p < 0.05$) or nearly significant ($p < 0.10$) the vegetation type (dominant plant) with greater abundance or biomass is noted.

	Trap Type		
Taxa Group	*Fallout*	*Emergence*	*Benthic*
Abundance			
All Taxa	0.820	--	0.003 (CALY)
Diptera	0.062 (CALY)	0.919	0.041 (CALY)
Chironomidae	0.027 (CALY)	0.268	0.045 (CALY)
Collembola	0.042 (PHAR)	--	N/A
Biomass			
All Taxa	0.236	0.161	0.694
Diptera	0.079 (CALY)	0.052 (PHAR)	0.411
Chironomidae	0.002 (CALY)	0.462	0.382

The results of the current study are similar to those from several studies comparing an invasive reed, *Phragmites australis*, to native saltmarsh cordgrass *Spartina alterniflora* on the east coast of the United States. For example, Angradi et al. (2001) found that chironomid larvae were more abundant in benthic core samples collected from native *S. alterniflora* habitats while collembolans were more abundant in the invasive *P. australis*; and Gratton and Denno (2005) found that collembolans, chironomids and other detritivores were more dominant in *P. australis* compared to *S. alterniflora*.

Invertebrate community structure was similar between *C. lyngbyei* and *P. arundinacea* within a given month for all three sample types. Community diversity, as measured by Shannon's index, was also similar between *C. lyngbyei* and *P. arundinacea*, except for fallout trap invertebrates, which were more diverse in *P. arundinacea* during all three months. In this respect our results differed from the above-mentioned studies on *Phragmites* and *Spartina*, in which the invasive plant was not only associated with lower taxa richness, but community composition also differed between the two plant types. Based on the *Phragmites-Spartina* studies and on several reviews of the literature on effects of invasive plants on arthropods, we might have expected more definitive community structure results from our study. For example, in a meta-analysis of 56 studies, van Hengstum et al. (2014) found that habitats dominated by invasive plant species had a 29% lower arthropod abundance and a 17% lower taxonomic richness compared with non-invaded habitats. In a review evaluating 87 journal articles, Litt et al. (2015) reported that in the presence of invasive plants, the total abundance of arthropods decreased in 62% of studies and increased in 15%, while taxonomic richness decreased in 48% of studies and increased in 13%. However, these studies provide other insights as to why we observed overall similarities between *C. lyngbyei* and *P. arundinacea* in the abundance, diversity, and community composition of all invertebrates taxa combined. First, van Hengstum et al. (2014) found that woody invasive plants had a stronger negative impact on arthropod communities than herbaceous invasive plants, reducing abundance and richness by as much as 55% and 21%, respectively; these authors also surmised from their meta-analysis that loss of arthropod diversity is generally directly associated with loss of plant species richness. Thus, because we sampled largely monotypic stands of two herbaceous species in our study, differences were probably not as apparent as they would have been in a multi-species plant community that also included woody species. Second, Litt et al. (2015) found that detritivores were less likely to be negatively affected by invasive plants, in fact they increased in 67% of studies, likely in response to increased litter and decaying vegetation. No documented studies reviewed by Litt et al. (2015) showed decreased abundance of detritivores. Our samples were largely dominated by organisms with partly or exclusively detritivorous life histories (e.g., Collembola, Oligochaeta, larval stages of Chironomidae and other Diptera) and this may have contributed to the lack of differences between *C. lyngbyei* and *P. arundinacea* in diversity and community structure. Furthermore, we sampled relatively small patches of marsh where even though the target vegetation was dominant, other species were often within close proximity, which may have homogenized the communities to some degree (see landscape scale vegetation sampling results presented in section 3.2.2). Through the in situ detritus sampling we observed mixing of detrital material throughout the study area which may have also contributed to similarities in macroinvertebrate community structure between *C. lyngbyei* and *P. arundinacea* sites. Future invertebrate studies of a similar nature may benefit from collecting data in larger monotypic stands of the target vegetation.

Landscape Vegetation Effects on the Macroinvertebrate Community

At the landscape scale of comparison, density and biomass of macroinvertebrates varied when regressed against the percent cover of *C. lyngbyei* and *P. arundinacea*. However, despite the

relatively low R^2 values, the significant slopes associated with certain taxa provide important information about the mean change of these taxa in response to a change in the percent cover of *C. lyngbyei*. For example, there was a significant positive relationship between Chironomidae (density and biomass) from the fallout traps and *C. lyngbyei* in all months. Likewise, a negative relationship was found between landscape scale *P. arundinacea* cover and Chironomidae biomass from the fallout traps in all months as well as density in April. Although the landscape-level analyses did not reveal any significant relationships between Chironomidae and *C. lyngbyei* cover from emergence traps or benthic cores, taken together with the paired-sample analysis, the results demonstrate that reduction in *C. lyngbyei* cover, such as in the transition to *P. arundinacea*, will likely reduce the availability of Chironomidae as prey.

The relationship between all taxa and the percent cover of *C. lyngbyei* and *P. arundinacea* was not as apparent as for Chironomidae from fallout traps. This may be because some macroinvertebrate taxa increase while others decrease under differing plant covers. For example, although the landscape-level analyses did not detect an increase in Collembolla with increasing *P. arundinacea* cover, they were significantly more abundant in the *P. arundinacea* samples in fallout and emergent traps from the paired sampling. Litt and Steidl (2010) also reported changes in vegetation composition associated with increasing dominance of a nonnative grass to be detrimental for most insect groups, but beneficial for other groups. On the other hand, in their meta-analysis of 56 studies, van Hengstum et al. (2014) found no correlation between the percent canopy cover of the invasive species and the effect on arthropod abundance overall ($R^2 = 0.009$). This result, similar to the current study, indicates that the extent of the invasive vegetation was not a useful predictor of the magnitude of change in macroinvertebrate communities.

4.4 Conclusion

Hypothesis 1: *Macroinvertebrate (i.e., important salmon prey) density, biomass, and community are reduced in patches of P. arundinacea compared to patches of C. lyngbyei.*

While overall invertebrate community structure and species diversity were not negatively impacted by *P. arundinacea*, our results do demonstrate that the two salmon prey groups examined (all Diptera and Chironomidae) were reduced in *P. arundinacea* dominated areas. While density and biomass of these groups of invertebrates from fallout traps and benthic cores were greater in *C. lyngbyei*, only emergent Diptera biomass was higher in *P. arundinacea* than in *C. lyngbyei*. This suggests a negative effect on the production of juvenile salmon prey in areas dominated by *P. arundinacea*. However, because the main feeding stage of Chironomidae (i.e., larval stage) is detrivorous (detrivores are less likely to be affected by invasive plants than other feeding types, Litt et al. 2015) and because there appears to be a certain degree of detrital mixing within the study area, the difference between the two vegetation types may not be of a magnitude that affects overall trophic functional value for juvenile Chinook salmon.

Hypothesis 2 and 4: *The quantity and quality of available macrodetritus decreases with increasing percent cover of P. arundinacea. Macrodetritus production is lower in areas of higher percent cover of P. arundinacea.*

Above ground biomass, a surrogate for vegetation productivity was similar between the two target species. However, more *P. arundinacea* standing stock remained in the winter. The summer difference between vegetation types and the resulting detrital contribution was not significant, likely due to the high variability in the *P. arundinacea* biomass in summer and winter. The difference in the ratio of winter to summer biomass (an indication of how much plant is remaining in the winter and not broken down) between the two species was nearly significant with much more of the *P. arundinacea* plants remaining at the beginning of the next growing season. This means that in an area where *P. arundinacea* is more dominant and productive (i.e., not at the lower end of its range such as it was in the current study), a much larger proportion of the high marsh vegetation would be remaining in the winter and not contributed to the detrital pool compared to native sedges such as *C. lyngbyei*.

The in situ macrodetritus was not significantly different between the two species, again likely because of the high variability in the samples. More sampling was likely needed to reduce the variability and capture the patterns observed in the vegetation and detritus cover measurements, which indicated that *C. lyngbyei* detritus declined over the sampling period while *P. arundinacea* detritus increased. Thus, the timing of when *P. arundinacea* enters the detrital pool could be later than that of *C. lyngbyei*. The implication of this difference in timing is that less detrital material is available to salmon prey species in the spring from *P. arundinacea* than from *C. lyngbyei*.

Hypothesis 3: *Decomposition rates and detritus quality of P. arundinacea are lower than that of C. lyngbyei during the juvenile salmon migration period.*

The results of the litter bag study, in which the detritus constituents from each species were kept separate, indicated that the decay rate was significantly higher in the large mesh bags of *C. lyngbyei* and the C:N ratio was significantly lower (i.e., higher quality) in bags containing *C. lyngbyei*.

In summary, the quantity of detrital material available during the peak salmonid migration period is higher from *C. lyngbyei* than from *P. arundinacea* given the differences in timing of transition from standing stock to detritus and subsequent decomposition rate of the detritus. The quality of detritus is also higher from *C. lyngbyei* and presumably more beneficial to salmonid prey species.

4.5 Adaptive Management & Lessons Learned

The effects of *P. arundinacea* on the ecosystem function of tidal wetlands are numerous. Based on the nutrient and carbon cycling differences between *P. arundinacea* and the native sedge *C.*

lyngbyei found in this study, we infer that the direct ecosystem components affected include the wetland soil and the detritivores that rely on organic matter from decomposing plants, including some salmonid prey species. These important ecological cycles are affected by the timing, quantity, and quality of the organic matter constituents from *P. arundinacea*. The delayed detrital contribution from *P. arundinacea* may reduce resources to salmon prey species in the early spring when juvenile salmon are migrating through the system. In addition, the quantity of organic material contributed to the ecosystem was found to be higher from the native sedge than from *P. arundinacea*, although the amount of organic material from high marshes has generally been found to be higher than from low marshes (Hanson et al 2015; note Carex species are often found in the mid marsh and were included in the high marsh in that study). The quality of detritus produced from *C. lyngbyei* was found to be higher than that of *P. arundinacea* and presumably more beneficial to salmon prey species. Specifically, in the current study Chironomidae, often dominant in juvenile Chinook salmon diets in the lower Columbia River (Lott 2004; Spilseth and Simenstad 2011; Sagar et al. 2013), were found to be significantly reduced in the presence of *P. arundinacea* between Rkm 50 and 89 of the Columbia River.

In order to increase wetland capacity for high quality macrodetritus and macroinvertebrate production, restoration actions should target strategies that will result in the restoration of native sedge and grass species within the productive high marsh zone. In our study, *C. lyngbyei* was able to compete because it is highly adapted to the tidal conditions found in our study area; however, tidal energy diminishes considerably above approximately rkm 89 (Jay et al. 2015). Given the highly competitive nature of *P. arundinacea* and the reduced tidal influence in the fluvial dominated portion of the river, native species have a reduced competitive advantage. Therefore, restoration strategies should be developed to allow native species to gain a competitive advantage prior to establishment of *P. arundinacea*.

Control of existing *P. arundinacea* is another strategy to regain native high marsh plant species. In an analogous situation documented by Gratton and Denno (2005), removal of invasive Phragmites from native Spartina marshes using herbicides resulted in the rapid return of the native Spartina in less than five years. The return of Spartina was accompanied by the recovery of most original habitat characteristics and the arthropod assemblage associated with Spartina returned quickly to its pre-invasion state and was indistinguishable from that of un-invaded Spartina habitats. However, when considering large scale removal of *P. arundinacea*, it would be advisable to estimate whether or not decreases in salmon prey within *P. arundinacea* dominated habitats are large enough to impact availability to juvenile salmon. Because larval chironomids are detrivorous and may be less affected by invasive plants than other feeding types (see discussion above), *P. arundinacea* dominated habitats, while having decreased numbers of salmon prey species, may still produce enough of these organisms that overall trophic function for juvenile Chinook salmon is not affected. Thus, to determine if the magnitude of the effects caused by *P. arundinacea* can impact trophic function, it would be beneficial to conduct additional study to measure the production of prey in different vegetation types and compare it to estimated consumption by juvenile salmon.

This study was conducted in tidal herbaceous habitats of surge plain complexes in the lower Columbia River. These are important ecosystems that support a diverse species assemblage and have been subject to considerable habitat loss due to land conversion and urban development. Therefore, it is critical to improve our understanding of how continued *P. arundinacea* invasion in remaining tidal emergent wetlands throughout the river will interact with other anthropogenic impacts and natural conditions, and the ultimate effect this will have on lower Columbia River food webs. We also only conducted a single year of study, thus our results only reflect conditions during that time and may not be representative of average conditions over multiple years. In addition, the extent of our study area was limited to a short section of the lower river, which corresponded with a lower end of the *P. arundinacea* elevation range and the upper end of the *C. lyngbyei* range. Other areas of the lower river with larger proportions of high marsh habitat dominated by *P. arundinacea* may not contribute significant amounts of detrital material to the system.

The Estuary Partnership shares results from the monitoring program with other resource managers in the region. The Science Work Group is comprised of over 60 individuals from the lower Columbia River basin representing multiple regional entities (i.e., government agencies, tribal groups, academia, and private sector scientists) with scientific and technical expertise who provide support and guidance to the Estuary Partnership. Results of this study were presented and discussed at a monthly Science Work Group meeting in May 2015. In addition, a draft of this report was presented to the Expert Regional Technical Group (ERTG) in September 2015. Study results will be presented at the Columbia River Estuary Workshop in May 2016.

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6 Appendices

Appendix A. Study Site Photo Points

Site: CALY1 Photo Point: 1

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22 April 2014

21 May 2014

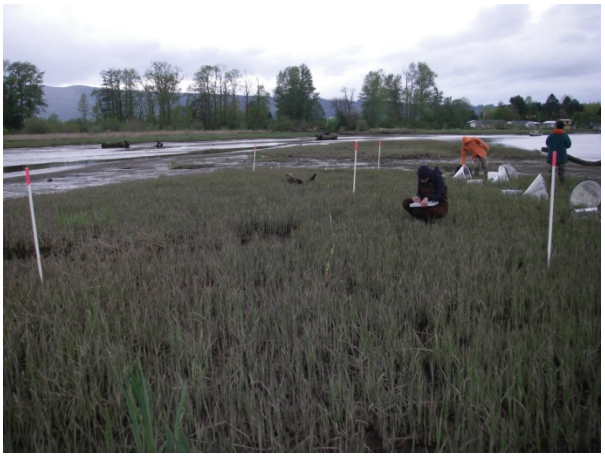
21 June 2014

5 August 2014

9 February 2015

Site: CALY1 Photo Point: 2

5 April 2014



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21 May 2014

21 June 2014

5 August 2014

February 2015

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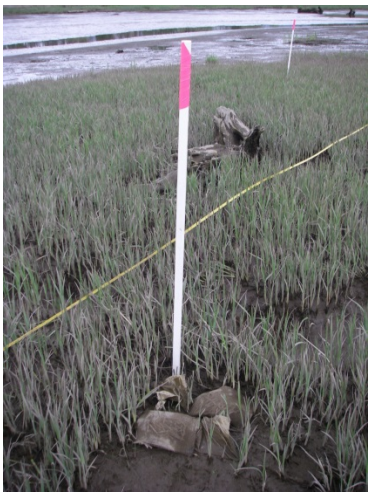

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21 May 2014

21 June 2014

5 August 2014

February 2015

Site: CALY1 Photo Point: 4

5 April 2014

22 April 2014

21 May 2014

21 June 2014

5 August 2014

February 2015

Site: CALY2 Photo Point: 1

April 2014

24 April 2014

19 May 2014

19 June 2014

2 August 2014

11 February 2015

Site: CALY2 Photo Point: 2

April 2014

24 April 2014

19 May 2014

19 June 2014

2 August 2014

11 February 2015

Site: CALY2 Photo Point: 3

April 2014

24 April 2014

19 May 2014

19 June 2014

2 August 2014

February 2015

Site: CALY2 Photo Point: 4

April 2014

24 April 2014

19 May 2014

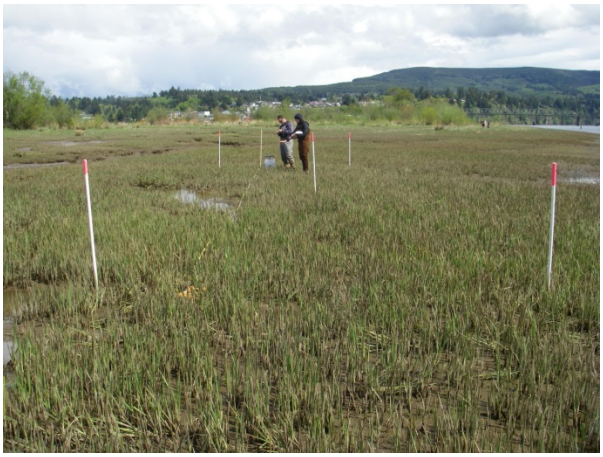
19 June 2014

2 August 2014

February 2015

Site: CALY3 Photo Point: 1

April 2014



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April 2014

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21 June 2014

August 2014

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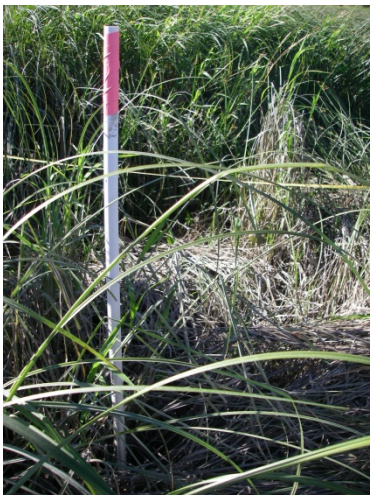
April 2014

22 April 2014

21 May 2014

21 June 2014



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April 2014

22 April 2014

21 May 2014

21 June 2014

6 August 2014

11 February 2015

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4 August 2014

February 2015

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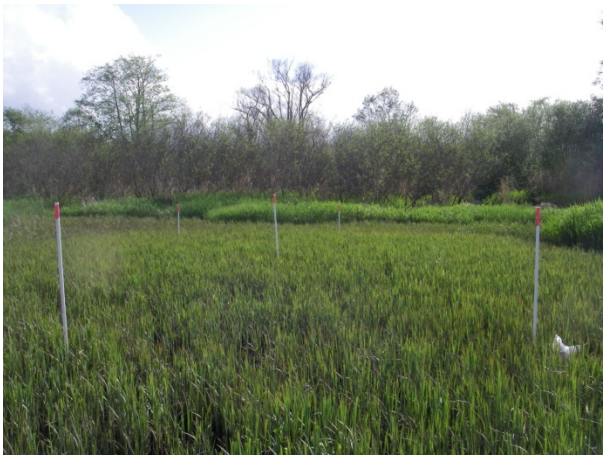
6 April 2014



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February 2015

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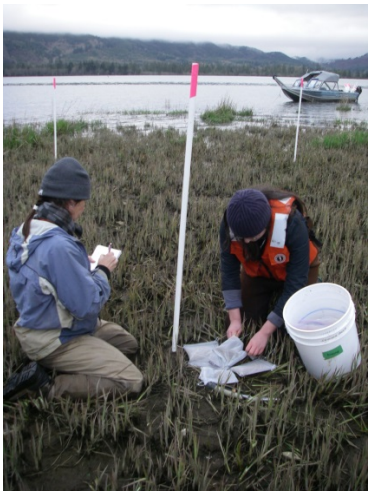

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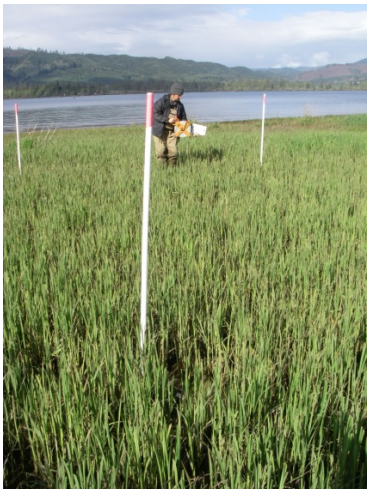

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19 June 2014

4 August 2014

February 2015

Site: CALY4 Photo Point: 4

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24 April 2014

19 May 2014

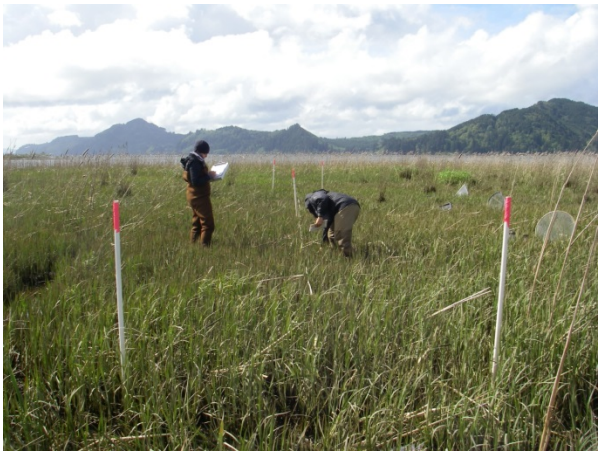
19 June 2014

4 August 2014

February 2015

Site: CALY5 Photo Point: 1

7 April 2014



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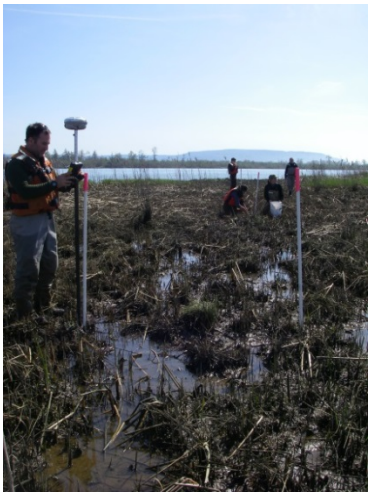
19 May 2014

19 June 2014

3 August 2014

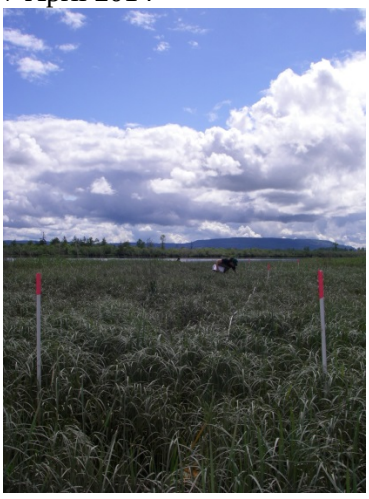
February 2015

Site: CALY5 Photo Point: 2



7 April 2014

24 April 2014



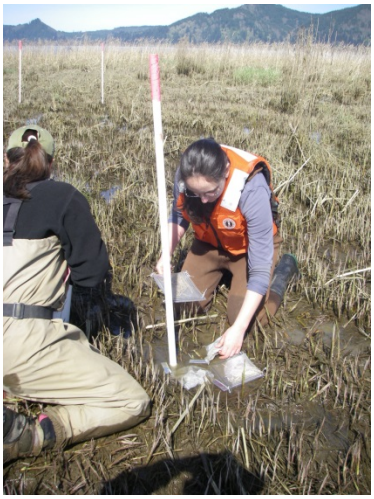
19 May 2014

19 June 2014

August 2014

February 2015

Site: CALY5 Photo Point: 3



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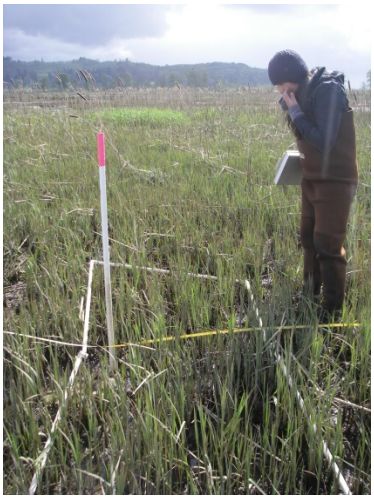

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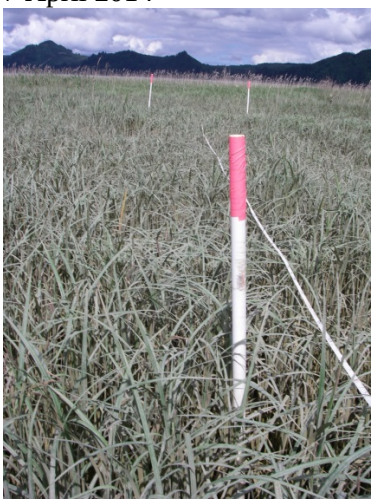

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19 June 2014

August 2014

February 2015

Site: CALY5 Photo Point: 4

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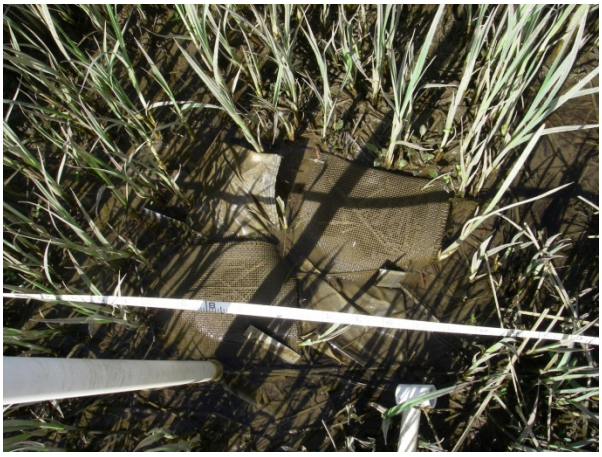


24 April 2014

19 May 2014

19 June 2014

August 2014

February 2015

Site: CALY6 Photo Point: 1

April 2014

22 April 2014

21 May 2014

21 June 2014

6 August 2014

11 February 2015

Site: CALY6 Photo Point: 2

April 2014

22 April 2014

21 May 2014

21 June 2014

6 August 2014

11 February 2015

Site: PHAR1 Photo Point: 1

5 April 2014

22 April 2014

21 May 2014

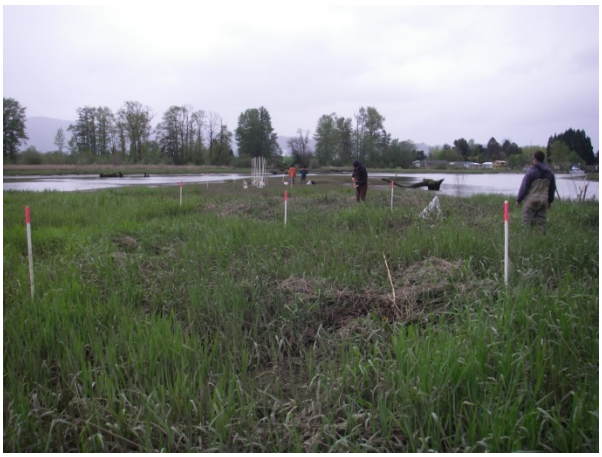
21 June 2014

5 August 2014

3 February 2015

Site: PHAR1 Photo Point: 2

5 April 2014



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21 May 2014

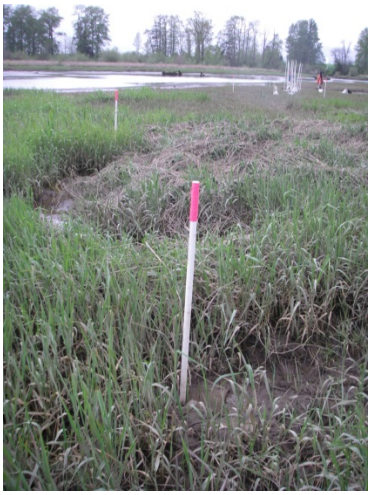
21 June 2014

5 August 2014

3 February 2015

Site: PHAR1 Photo Point: 3

5 April 2014



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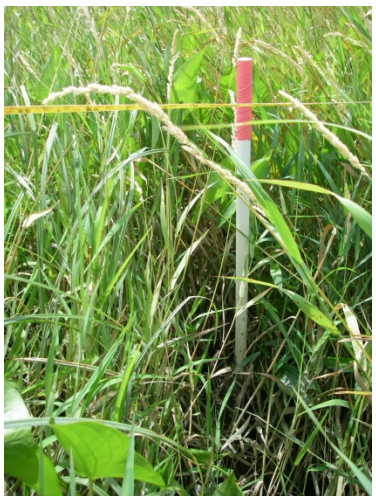
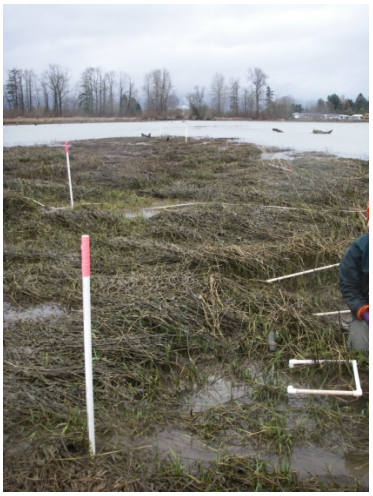
21 May 2014

21 June 2014

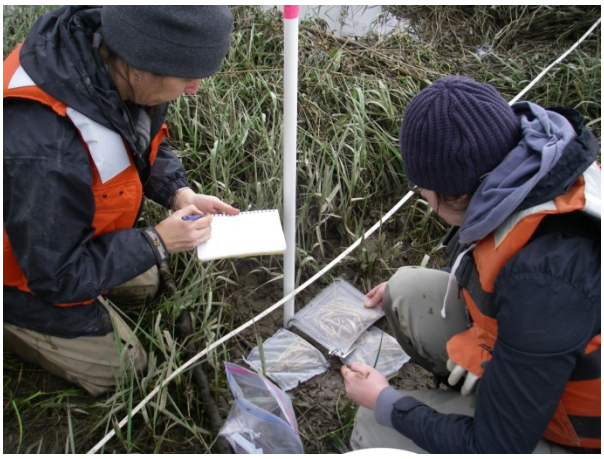


5 August 2014



3 February 2015

Site: PHAR1 Photo Point: 4



5 April 2014

22 April 2014

21 May 2014

21 June 2014

5 August 2014

3 February 2015

Site: PHAR2 Photo Point: 1

7 April 2014

24 April 2014

19 May 2014

19 June 2014

4 August 2014

February 2015

Site: PHAR2 Photo Point: 2

7 April 2014

24 April 2014

19 May 2014

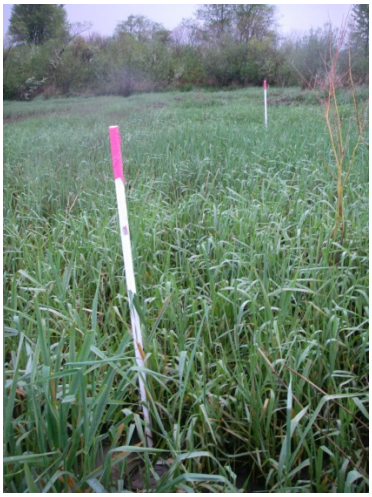
19 June 2014

4 August 2014

February 2015

Site: PHAR2 Photo Point: 3

7 April 2014



24 April 2014

19 May 2014

19 June 2014

4 August 2014

February 2015

Site: PHAR2 Photo Point: 4

7 April 2014

24 April 2014

19 May 2014

19 June 2014

4 August 2014

February 2015

Site: PHAR3 Photo Point: 1

6 April 2014

22 April 2014

21 May 2014

21 June 2014

6 August 2014

11 February 2015

Site: PHAR3 Photo Point: 2

April 2014

22 April 2014

21 May 2014

21 June 2014

6 August 2014

11 February 2015

Site: PHAR3 Photo Point: 3

6 April 2014

22 April 2014

21 May 2014

21 June 2014

6 August 2014

11 February 2015

Site: PHAR3 Photo Point: 4

6 April 2014

22 April 2014

21 May 2014

21 June 2014

August 2014

11 February 2015

Site: PHAR4 Photo Point: 1

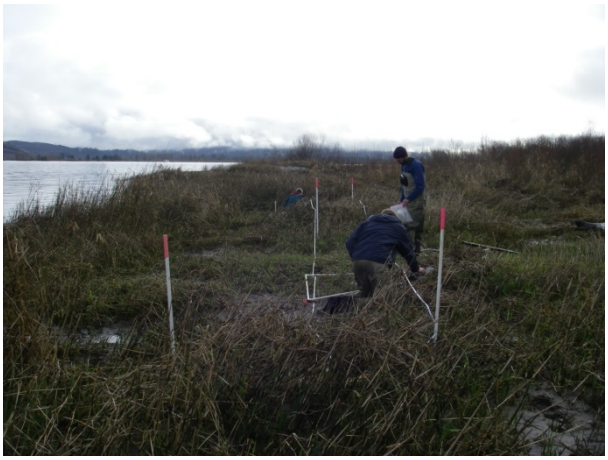
April 2014

24 April 2014

19 May 2014

19 June 2014

4 August 2014



10 February 2015

Site: PHAR4 Photo Point: 2

April 2014

24 April 2014

19 May 2014

19 June 2014

4 August 2014

10 February 2015

Site: PHAR4 Photo Point: 3

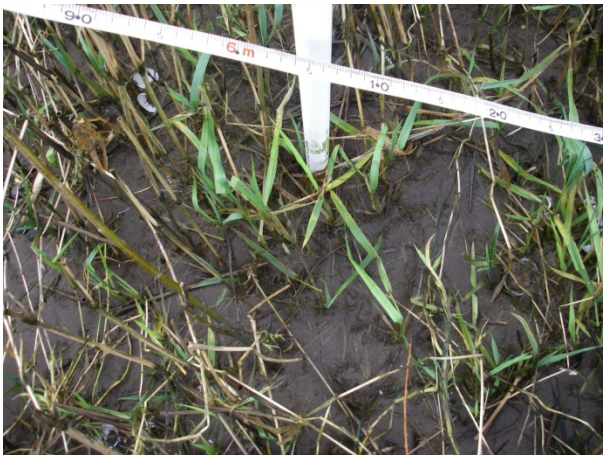
6 April 2014

24 April 2014

19 May 2014

19 June 2014

4 August 2014



10 February 2015

Site: PHAR4 Photo Point: 4

April 2014

24 April 2014

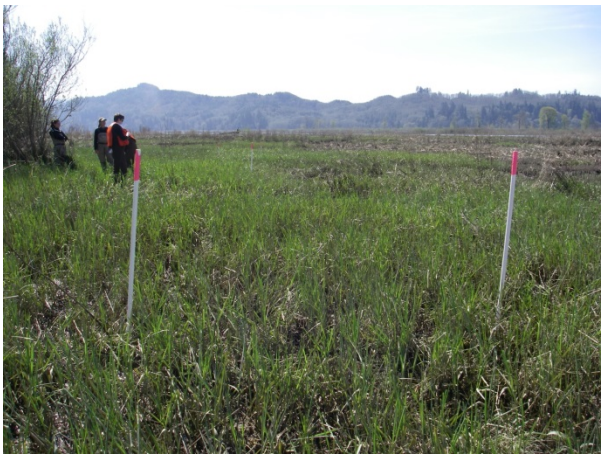
19 May 2014

19 June 2014

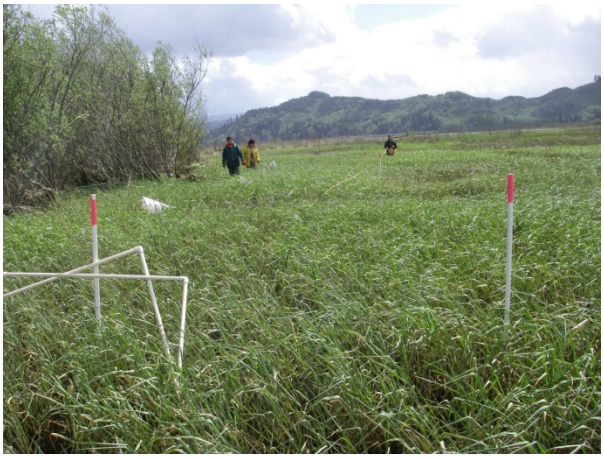
4 August 2014

10 February 2015

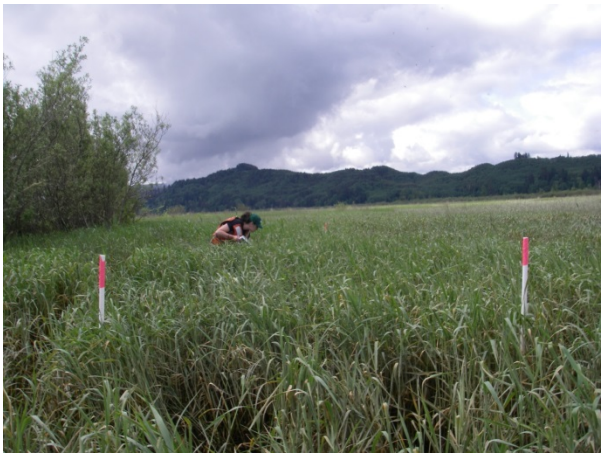
Site: PHAR5 Photo Point: 1



7 April 2014



24 April 2014



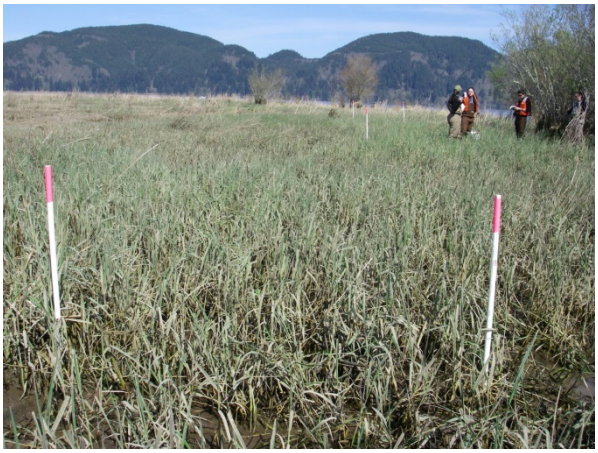
19 May 2014

19 June 2014

3 August 2014

February 2015

Site: PHAR5 Photo Point: 2



7 April 2014

24 April 2014

19 May 2014

19 June 2014

3 August 2014

February 2015

Site: PHAR5 Photo Point: 3

7 April 2014

24 April 2014

19 May 2014

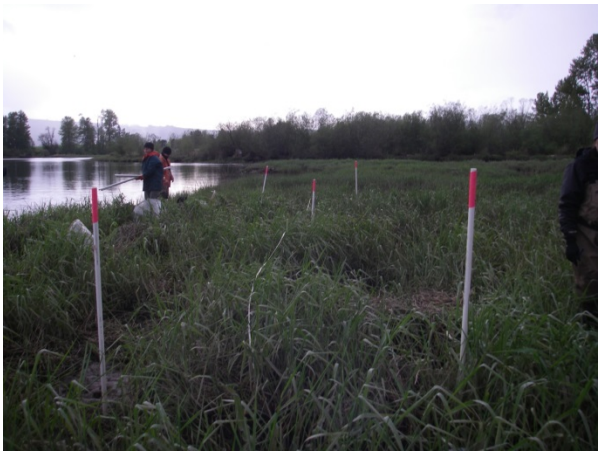
19 June 2014

3 August 2014

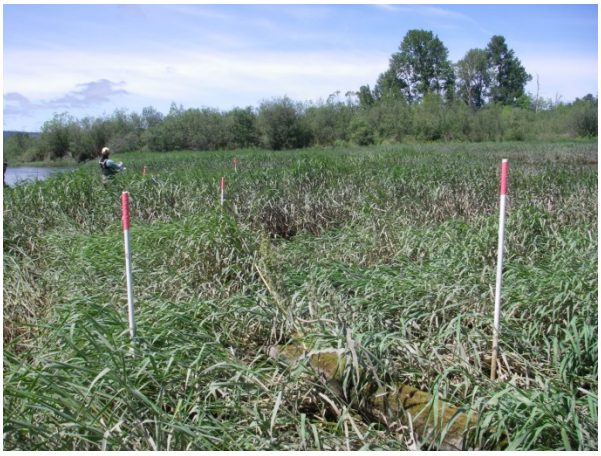
February 2015

Site: PHAR6 Photo Point: 1

7 April 2014



22 April 2014



21 May 2014

21 June 2014

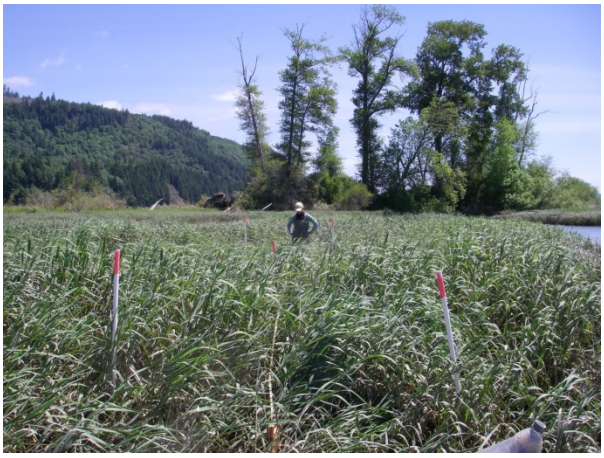
5 August 2014

9 February 2015

Site: PHAR6 Photo Point: 2

7 April 2014

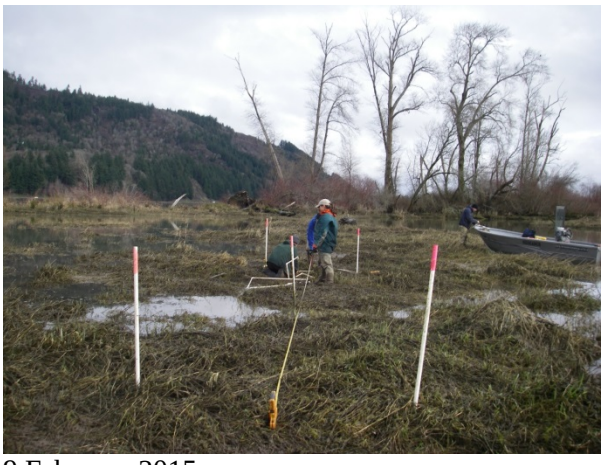
22 April 2014



21 May 2014

21 June 2014

5 August 2014



9 February 2015

Site: PHAR6 Photo Point: 3

7 April 2014

22 April 2014

21 May 2014

21 June 2014

5 August 2014

9 February 2015

Site: PHAR6 Photo Point: 4

April 2014

22 Late April 2014

21 May 2014

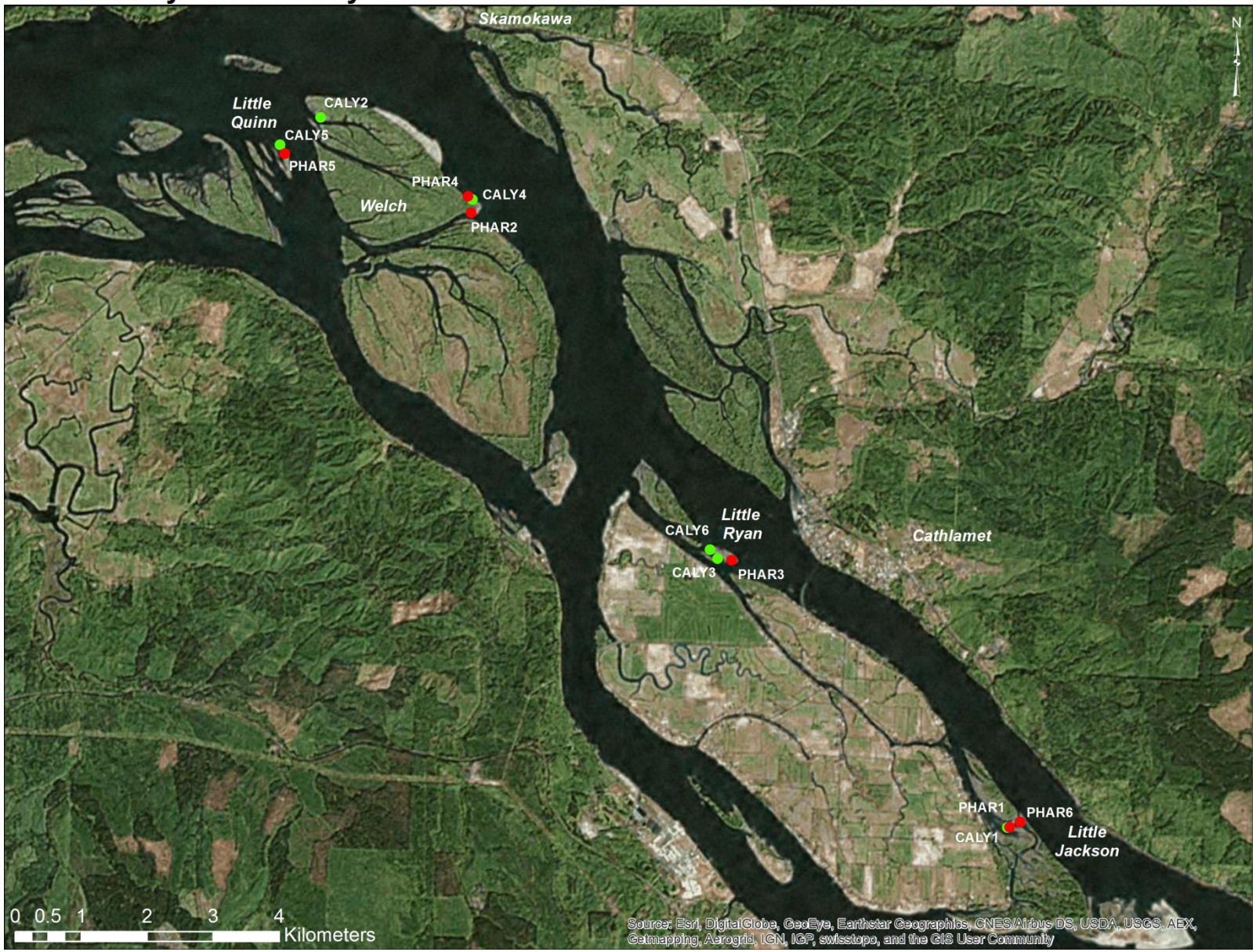
21 June 2014

5 August 2014

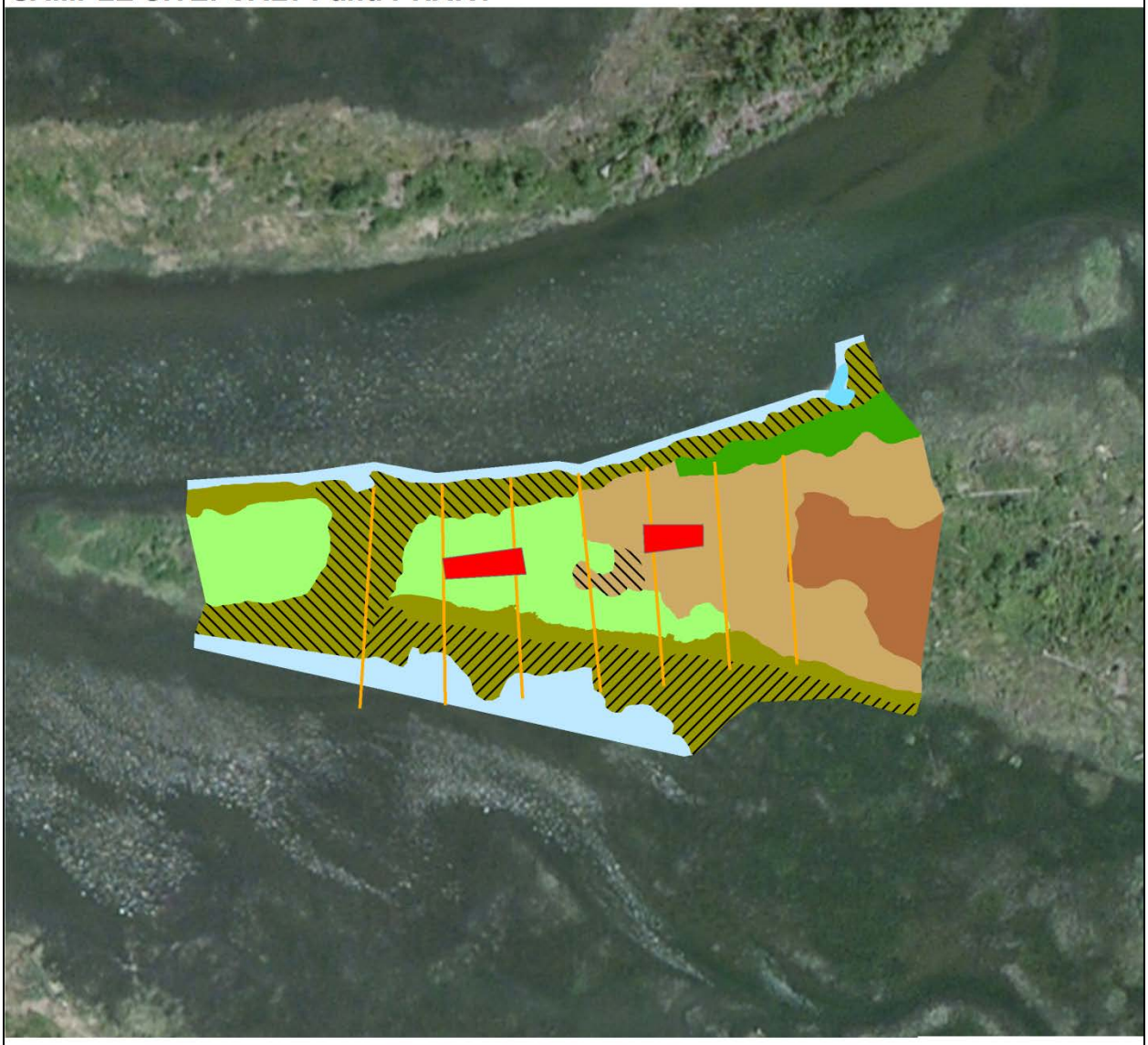
9 February 2015

Appendix B. Site Maps

Reed Canary Grass Study Sites



LOCATION: Little Jackson Island
SAMPLE SITE: CALY1 and PHAR1



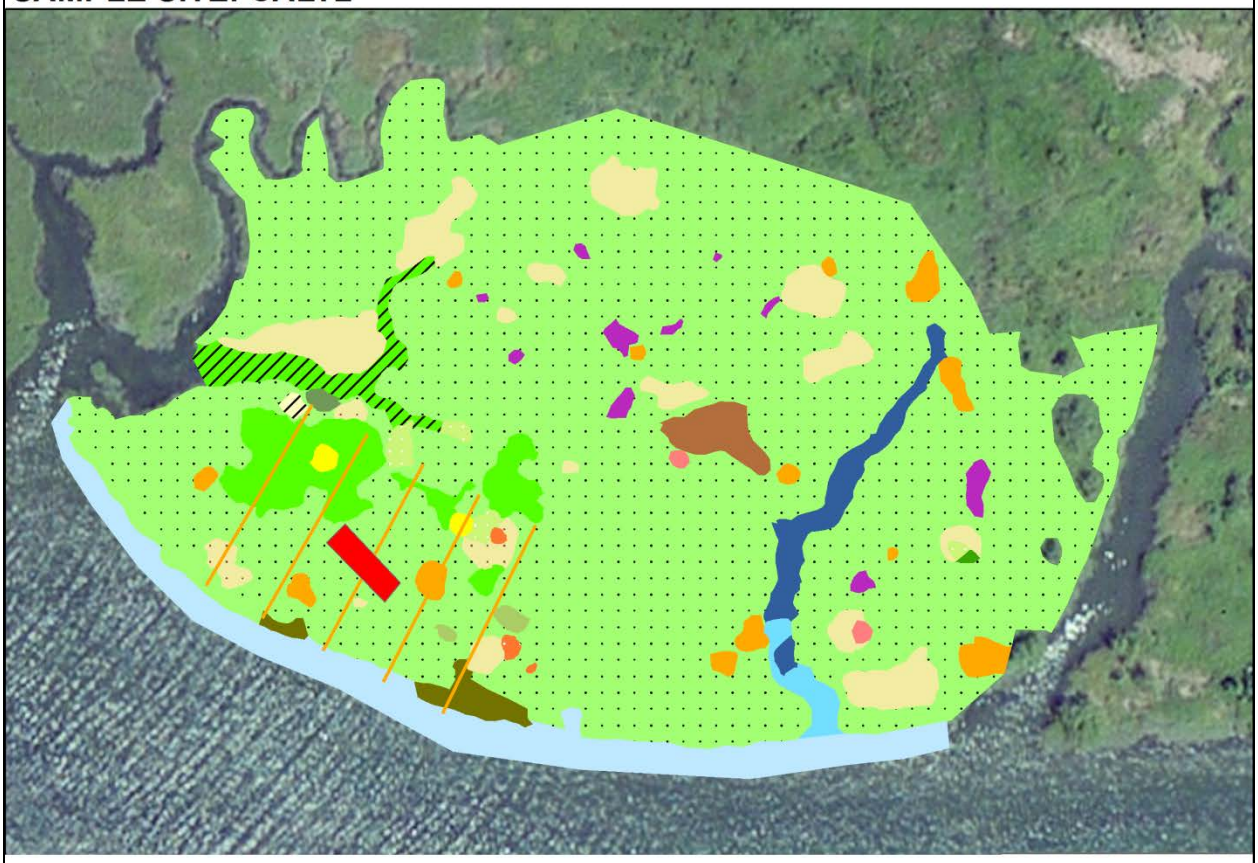
Vegetation Mapping

0 10 20 40 60 80 Meters

- Carex lyngbyei
- Eleocharis palustris, Bidens cernua, Schoenoplectus americanus
- E. palustris, Sagittaria latifolia
- E. palustris, S. latifolia, S. americanus
- Phalaris arundinacea, C. lyngbyei
- P. arundinacea, C. lyngbyei, S. latifolia
- P. arundinacea, Lythrum salicaria, Salix saplings
- Potamogeton natans
- S. latifolia
- open water
- Sample Area
- Vegetation Cover Transects

N

LOCATION: Welch Island
SAMPLE SITE: CALY2



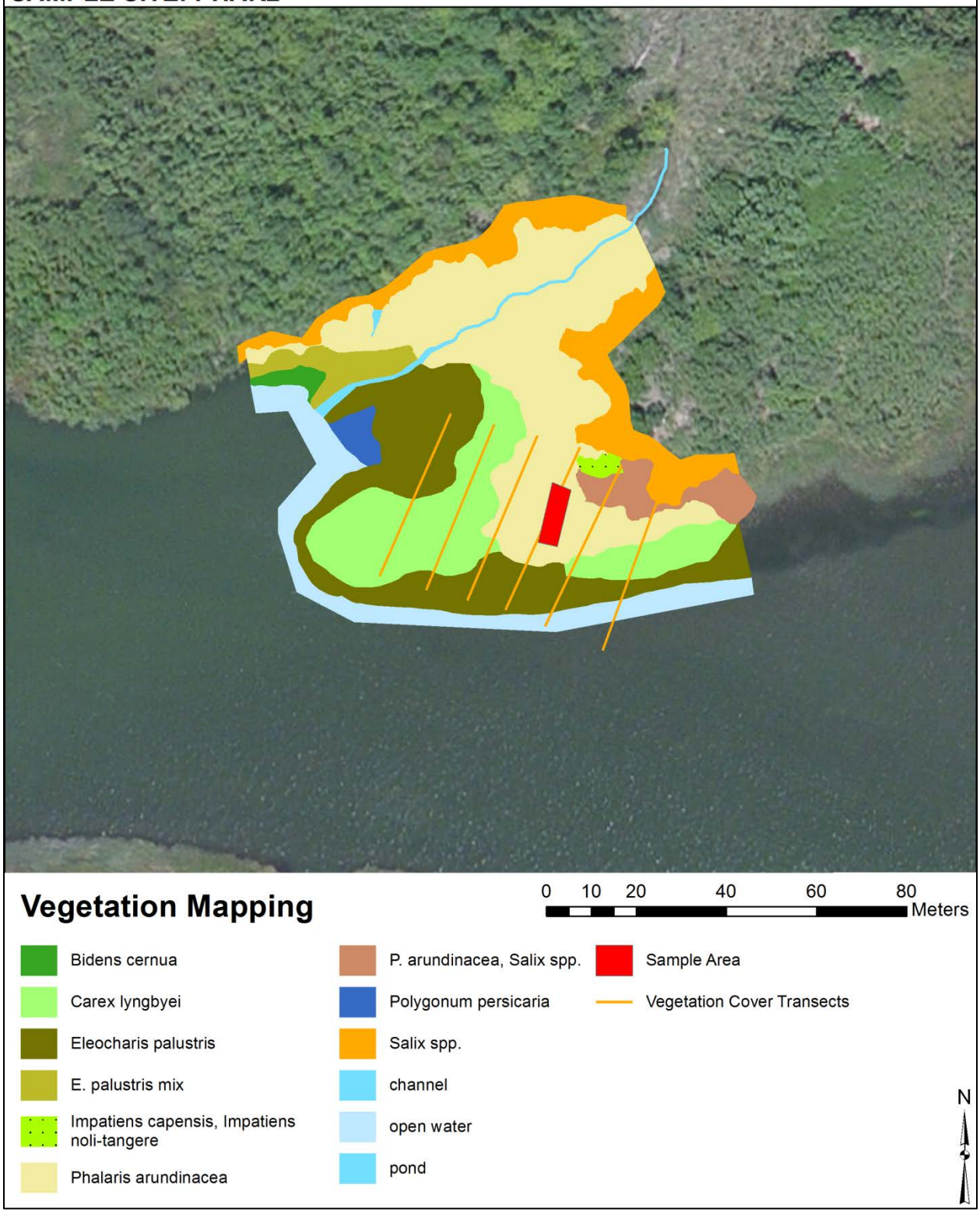
Vegetation Mapping

0 10 20 40 60 80
Meters

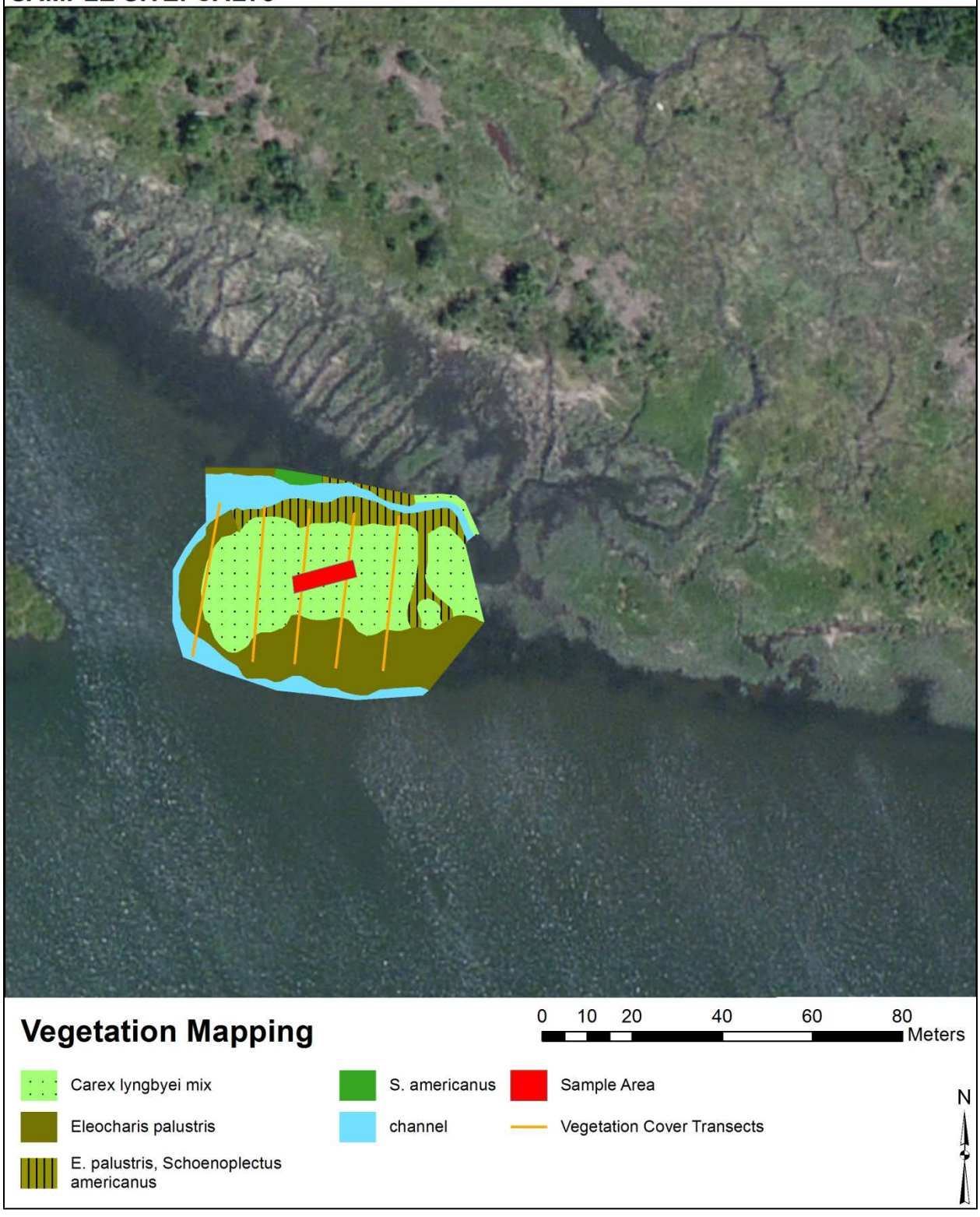
- Carex lyngbyei
- C. lyngbyei mix
- C. lyngbyei, Iris pseudacorus
- C. lyngbyei, Sagittaria latifolia
- Eleocharis palustris
- E. palustris, C. lyngbyei, S. latifolia
- I. pseudacorus
- Lythrum salicaria
- Phalaris arundinacea
- P. arundinacea mix
- P. arundinacea, I. pseudacorus
- P. arundinacea, L. salicaria
- P. arundinacea, S. latifolia
- S. latifolia
- S. latifolia, Polygonum persicaria, E. palustris
- S. latifolia, channel
- Salix saplings
- Salix spp.
- Salix spp., L. salicaria
- channel
- open water
- Sample Area
- Vegetation Cover Transects

N

LOCATION: Welch Island
SAMPLE SITE: PHAR2



LOCATION: Little Ryan Island
SAMPLE SITE: CALY3



LOCATION: Little Ryan Island
SAMPLE SITE: PHAR3

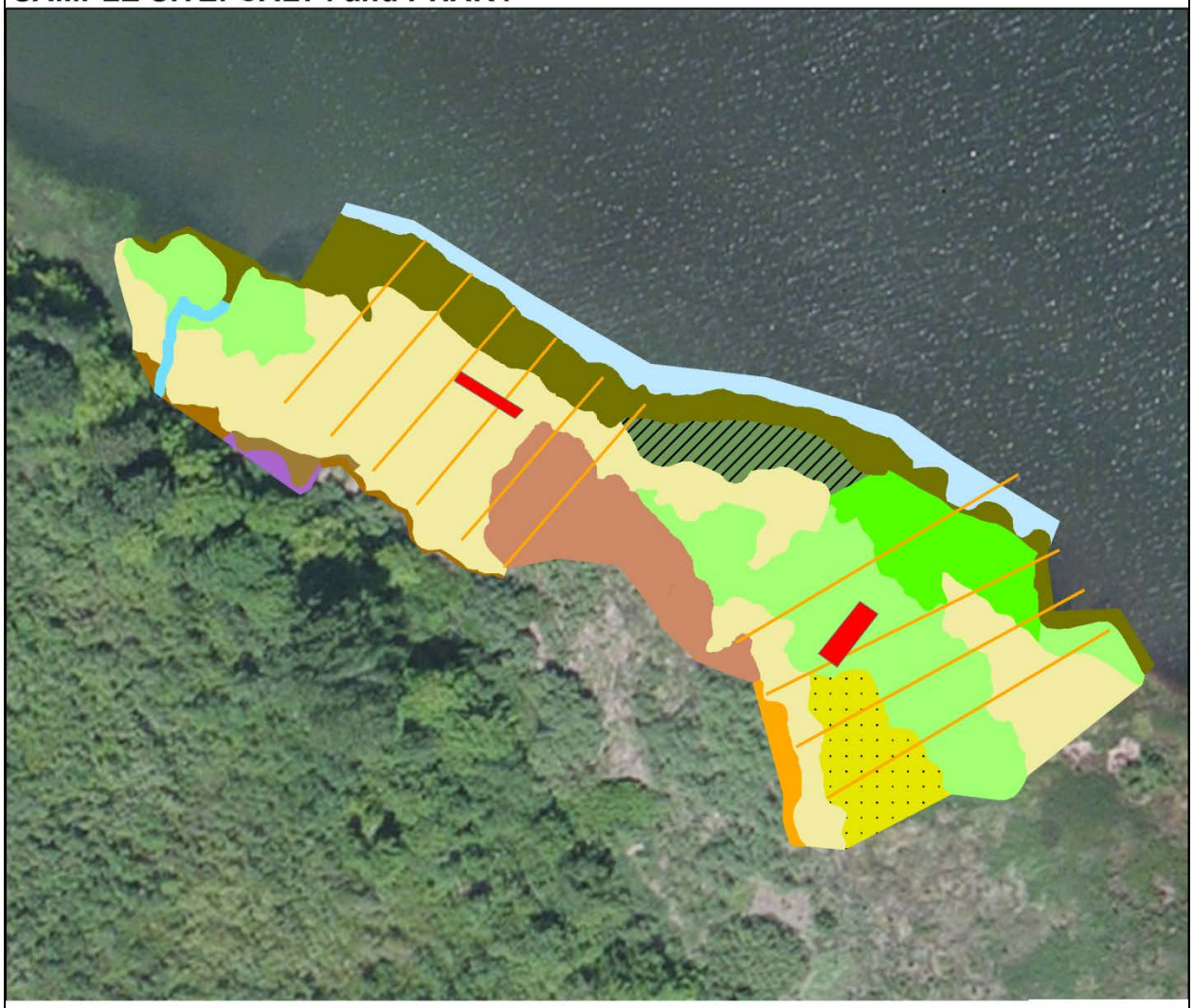
Vegetation Mapping

0 10 20 40 60 80 Meters

- Carex lyngbyei
- Eleocharis palustris
- E. palustris, C. lyngbyei
- E. palustris, C. lyngbyei, Juncus oxymeris
- E. palustris, C. lyngbyei, Schoenoplectus americanus
- Impatiens capensis, Impatiens noli-tangere, Mentha spp., Iris pseudacorus
- Phalaris arundinacea
- P. arundinacea mix
- P. arundinacea, Salix spp.
- Salix saplings
- Salix spp.
- channel
- open water
- Sample Area
- Vegetation Cover Transects

N

LOCATION: Welch Island
SAMPLE SITE: CALY4 and PHAR4



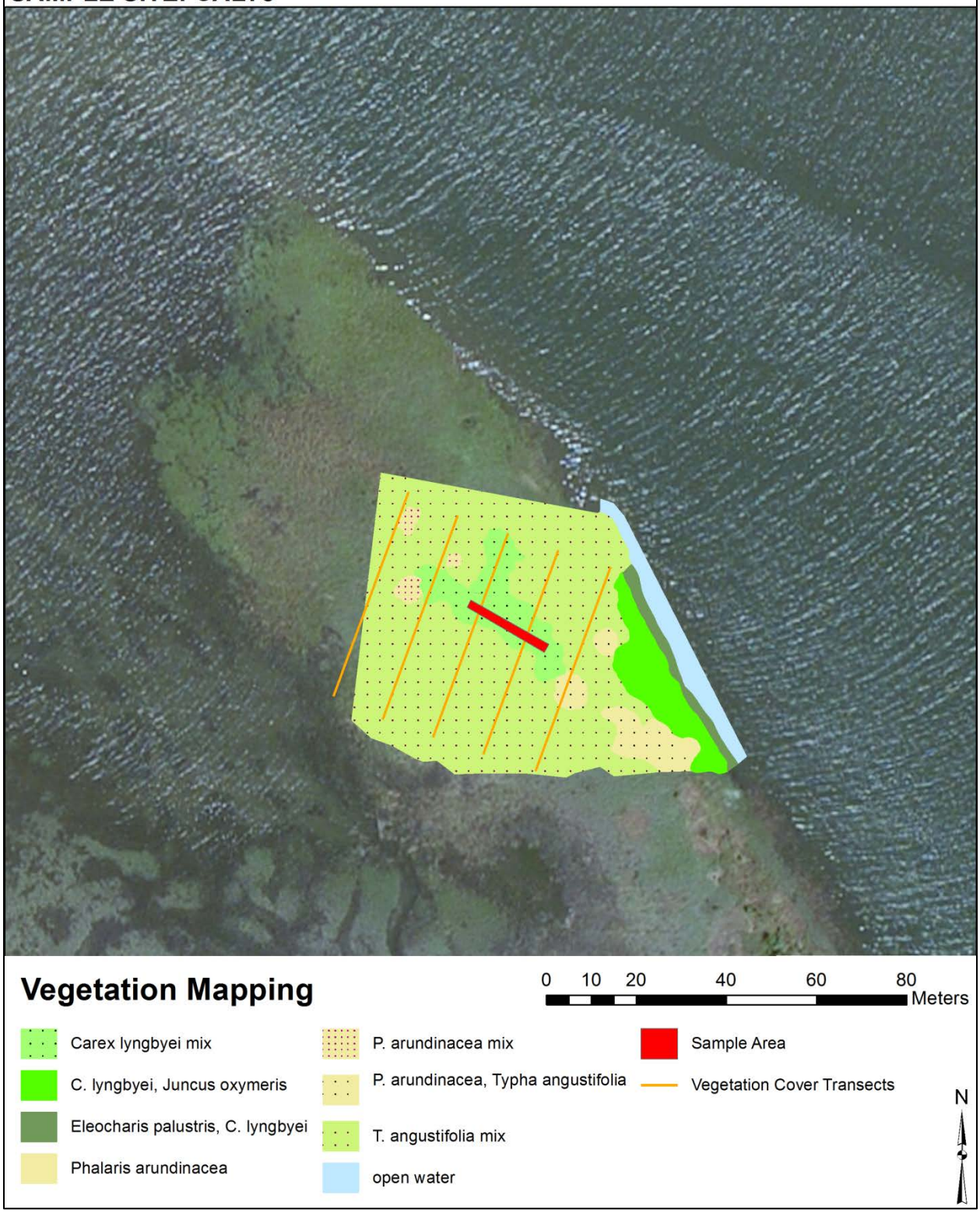
Vegetation Mapping

0 10 20 40 60 80 Meters

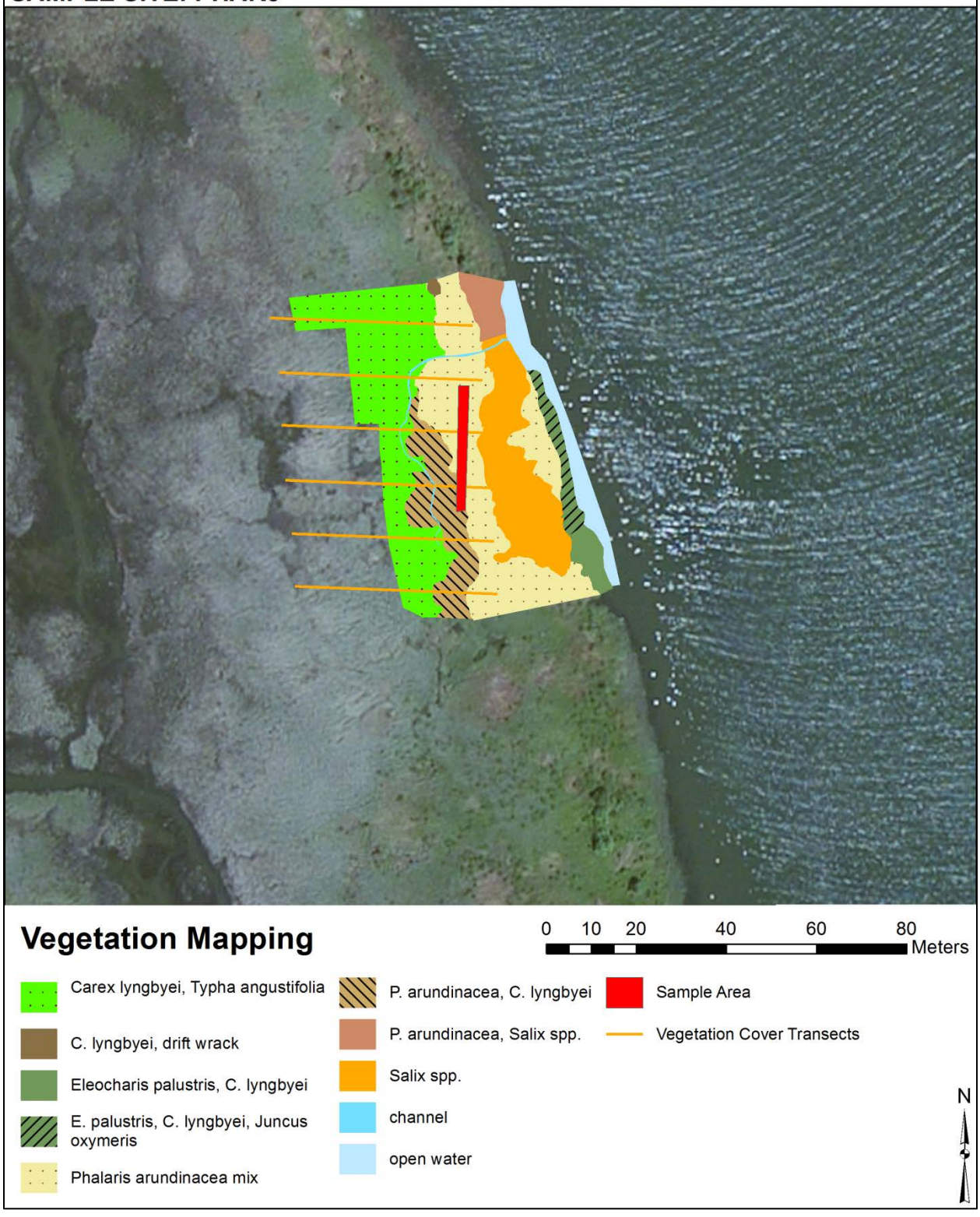
- Carex lyngbyei
- C. lyngbyei, Juncus oxymeris
- Eleocharis palustris
- E. palustris, C. lyngbyei, J. oxymeris
- Phalaris arundinacea
- P. arundinacea, Salix spp.
- Rubus armeniacus, Alnus rubra, Populus balsamifera
- Salix sitchensis, Cornus sericea, A. rubra, P. balsamifera
- Salix spp.
- Typha angustifolia
- channel
- detritus
- open water
- Sample Area
- Vegetation Cover Transects

N

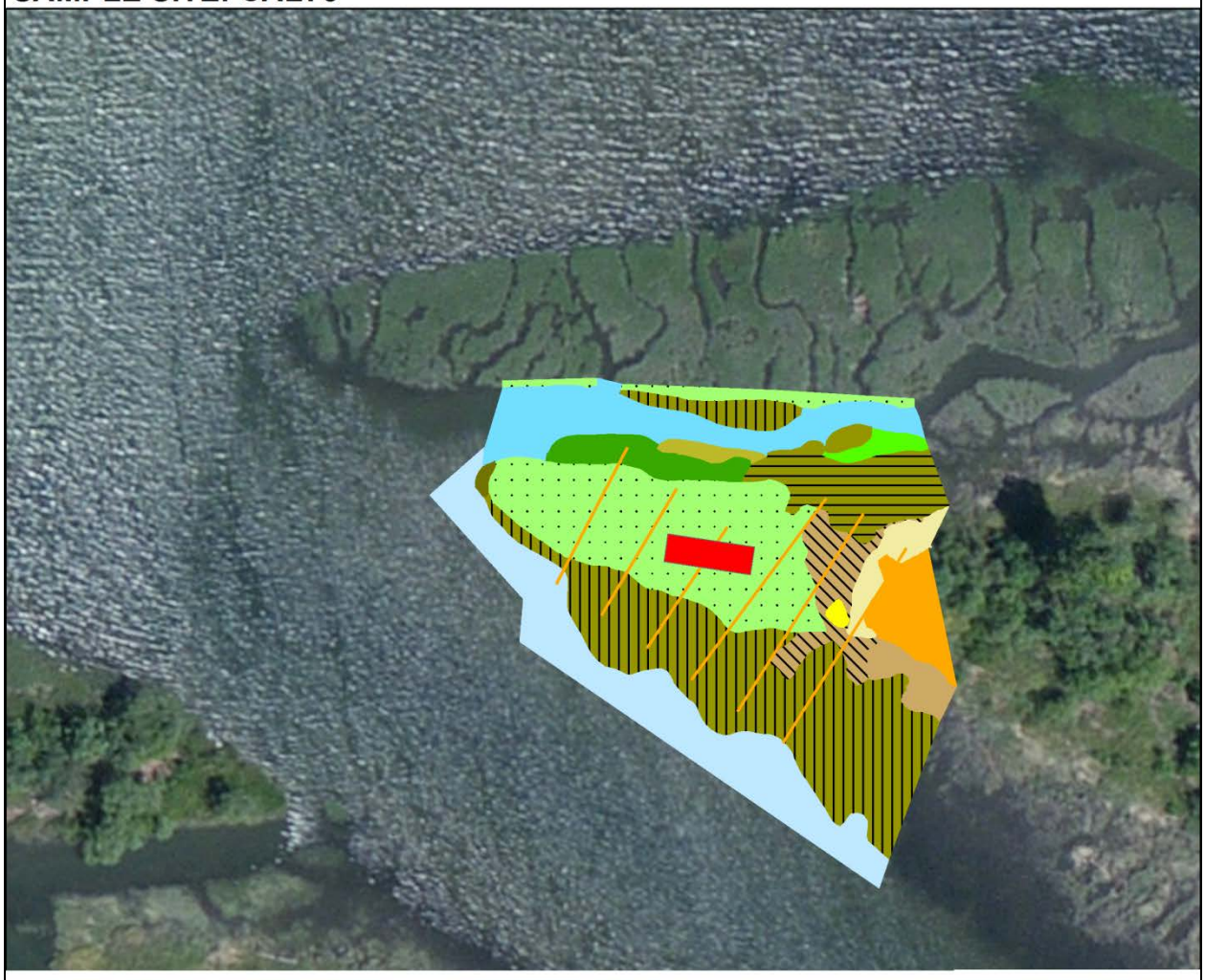
LOCATION: Little Quinns Island
SAMPLE SITE: CALY5



LOCATION: Little Quinns Island
SAMPLE SITE: PHAR5



LOCATION: Little Ryan Island
SAMPLE SITE: CALY6



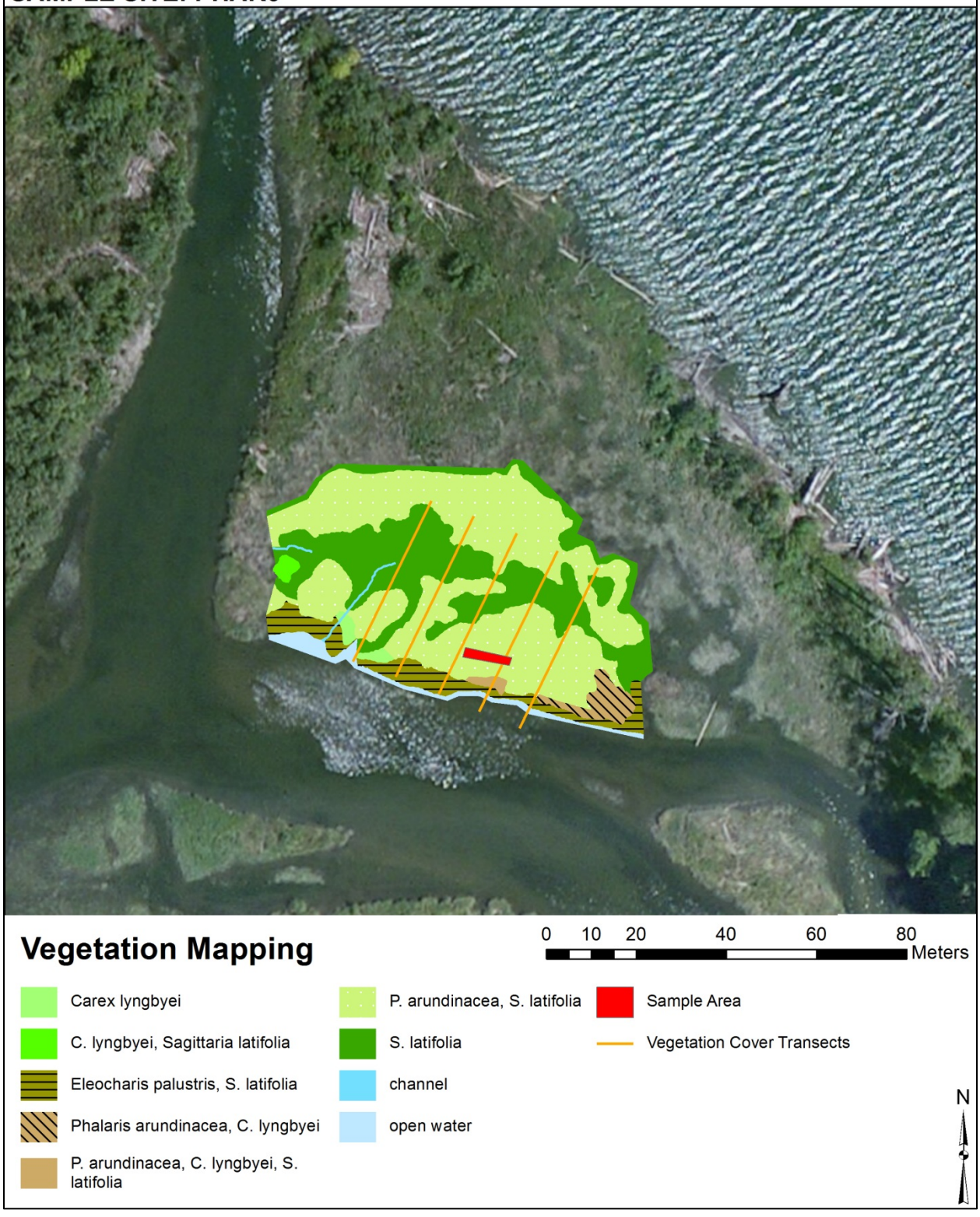
Vegetation Mapping

0 10 20 40 60 80 Meters

- Carex lyngbyei mix
- C. lyngbyei, Juncus oxymeris
- Eleocharis palustris
- E. palustris mix
- E. palustris, Bidens cernua
- E. palustris, Sagittaria latifolia
- E. palustris, Schoenoplectus americanus
- Iris pseudacorus
- Phalaris arundinacea
- P. arundinacea, C. lyngbyei
- P. arundinacea, C. lyngbyei, J. oxymeris
- S. latifolia
- Salix spp.
- channel
- open water
- Sample Area
- Vegetation Cover Transects

N

LOCATION: Little Jackson Island
SAMPLE SITE: PHAR6



Appendix C. Percent Cover for Study Sites

Table C.1 Monthly average percent cover at the study plots CALY1 and CALY2. Native status designations: M = mixed, N= no, not native, Y=yes, native.

				CALY1								CALY2						
				April		May		June		August		April		May		June		August
Species Code	Scientific Name	Common Name	Native	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	
AGSP	Agrostis sp.	bentgrass	M	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.0	0.0	0.0	0.0	ND
AGST	Agrostis stolonifera L.	creeping bentgrass	N	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	3.7	ND
ALTR	Alisma triviale	northern water plaintain	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	2.3	ND
AREG	Argentina egedii	Pacific silverweed	Y	0.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	2.3	2.3	3.4	2.3	6.4	6.8	ND
CAHE	Callitriche heterophylla	Water starwort; Twoheaded water starwort	Y	0.8	0.5	3.3	3.6	0.6	0.5	0.5	0.6	0.0	0.0	0.0	0.0	0.0	0.0	ND
CALY	Carex lyngbyei	Lyngby sedge	Y	30.0	13.1	35.0	6.5	43.8	10.9	80.0	5.8	39.4	10.5	33.8	8.8	43.1	14.1	ND
CAPA	Caltha palustris	Yellow marsh marigold	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.9	8.0	7.0	5.1	6.4	5.0	ND
ELPA	Eleocharis palustris	Common spikerush	Y	0.0	0.0	0.1	0.4	0.1	0.4	0.0	0.0	0.9	1.7	0.0	0.0	2.6	3.7	ND
EPCI	Epilobium ciliatum	Willow herb	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	3.5	0.0	0.0	ND
JUOX	Juncus oxymeris	Pointed rush	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	2.4	0.4	0.5	ND
LEOR	Leersia oryzoides	Rice cutgrass	Y	0.0	0.0	0.0	0.0	0.0	0.0	8.8	2.5	0.0	0.0	0.0	0.0	0.0	0.0	ND
LYAM	Lysichiton americanus	Skunk cabbage	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	2.3	1.3	2.3	0.6	1.8	ND
LYAM2	Lycopus americanus	American water horehound	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	2.3	0.0	0.0	0.0	0.0	ND
LYSA	Lythrum salicaria	Purple loosestrife	N	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.1	4.1	0.0	0.0	ND
MIGU	Mimulus guttatus	Yellow monkeyflower	Y	0.4	0.5	0.0	0.0	0.0	0.0	0.3	0.5	1.1	1.6	0.0	0.0	0.0	0.0	ND
MYSP	Myosotis laxa, M. scorpioides	Small forget-me-not, Common forget-me-not	M	1.8	2.1	2.8	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ND
OESA	Oenanthe sarmentosa	Water parsley	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	2.2	1.9	5.3	1.4	2.3	ND
PHAR	Phalaris arundinacea	Reed canary grass	N	0.1	0.4	1.0	1.7	3.9	2.1	0.0	0.0	0.3	0.5	0.0	0.0	0.0	0.0	ND
PLDI	Platanthera dilatata	white bog orchid	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.0	0.0	0.0	0.0	ND
POHY	Polygonum hydropiper, P. hydropiperoides	Waterpepper, mild waterpepper, swamp smartweed	M	0.0	0.0	0.0	0.0	2.3	2.3	0.8	0.5	0.0	0.0	0.0	0.0	2.0	2.5	ND
POPE	Polygonum persicaria	Spotted ladysthumb	N	0.0	0.0	0.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ND
RASP	Ranunculus sp.	buttercup	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	ND
RUCR	Rumex crispus	Curly dock	N	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.5	ND
SISU	Sium suave	Hemlock waterparsnip	Y	0.0	0.0	2.0	2.5	0.8	1.8	0.0	0.0	0.5	0.5	0.0	0.0	4.4	1.8	ND
SYSU	Symphyotrichum subspicatum	Douglas aster	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	5.3	ND
BG		bare ground		30.0	26.5	33.1	21.4	2.5	7.1	8.8	10.3	1.3	2.3	5.0	3.8	0.0	0.0	ND
CALY-D	dead Carex lyngbyei	dead Lyngby sedge		0.0	0.0	0.0	0.0	0.0	0.0	7.5	6.5	19.4	7.3	0.0	0.0	0.0	0.0	ND
DETRITUS		detritus		38.8	12.5	19.4	21.3	45.6	15.5	0.0	0.0	46.3	6.9	38.1	7.5	26.9	10.0	ND
DW		drift wrack		0.0	0.0	0.0	0.0	0.6	1.8	3.8	4.8	0.0	0.0	0.0	0.0	0.0	0.0	ND
LITTER		litter		0.1	0.4	0.0	0.0	0.0	0.0	1.5	2.4	0.6	1.8	0.0	0.0	0.0	0.0	ND
LWD		large woody debris		0.0	0.0	3.8	8.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ND
SD		standing dead		0.0	0.0	0.0	0.0	0.8	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ND
SMH		small mixed herbs		0.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	2.5	2.1	0.1	0.4	0.0	0.0	ND
UID		unidentified species		0.0	0.0	0.0	0.0	0.6	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ND

Table C2. Monthly average percent cover at the study plots CALY3 and CALY4. Native status designations: M = mixed, N= no, not native, Y=yes, native.

				CALY3								CALY4						
				April		May		June		August		April		May		June		August
Species Code	Scientific Name	Common Name	Native	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	
ALTR	Alisma triviale	northern water plaintain	Y	0.0	0.0	0.0	0.0	0.6	1.8	0.5	0.6	0.0	0.0	0.0	0.0	0.1	0.4	ND
AREG	Argentina egedii	Pacific silverweed	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.5	0.0	0.0	0.0	0.0	ND
BICE	Bidens cernua	Nodding beggars-ticks	Y	0.0	0.0	0.0	0.0	0.0	0.0	1.3	2.5	0.0	0.0	0.0	0.0	0.0	0.0	ND
CAHE	Callitriche heterophylla	Water starwort; Twoheaded water starwort	Y	0.1	0.4	2.1	2.4	5.1	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ND
CALY	Carex lyngbyei	Lyngby sedge	Y	26.4	11.6	34.4	12.7	39.5	30.9	65.0	33.9	38.1	11.0	41.9	15.8	58.1	8.8	ND
DECE	Deschampsia cespitosa	Tufted hairgrass	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	2.1	0.0	0.0	0.0	0.0	ND
ELPA	Eleocharis palustris	Common spikerush	Y	0.5	0.5	3.1	3.7	2.9	2.3	0.3	0.5	1.8	2.1	5.6	5.0	5.0	2.7	ND
JUOX	Juncus oxymeris	Pointed rush	Y	0.0	0.0	0.6	1.8	0.0	0.0	2.8	2.6	0.3	0.5	0.6	1.8	1.3	2.3	ND
LEOR	Leersia oryzoides	Rice cutgrass	Y	0.0	0.0	0.0	0.0	0.0	0.0	3.8	2.5	0.0	0.0	0.0	0.0	0.0	0.0	ND
LIAQ	Limosella aquatica	Water mudwort	Y	0.0	0.0	0.0	0.0	0.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ND
LIOC	Lilaeopsis occidentalis	Western lilaeopsis	Y	0.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ND
MIGU	Mimulus guttatus	Yellow monkeyflower	Y	0.3	0.5	0.0	0.0	0.0	0.0	0.3	0.5	3.5	2.1	0.0	0.0	0.0	0.0	ND
MYSP	Myosotis laxa, M. scorpioides	Small forget-me-not, Common forget-me-not	M	0.0	0.0	4.0	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ND
OESA	Oenanthe sarmentosa	Water parsley	Y	0.0	0.0	0.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.9	1.7	1.4	2.3	ND
PHAR	Phalaris arundinacea	Reed canary grass	N	0.1	0.4	0.0	0.0	2.9	3.5	3.8	4.8	0.0	0.0	0.0	0.0	3.3	2.4	ND
POHY	Polygonum hydropiper, P. hydropiperoides	Waterpepper, mild waterpepper, swamp smartweed	M	0.0	0.0	0.0	0.0	0.6	0.5	0.5	0.6	0.0	0.0	0.6	1.8	6.9	2.6	ND
POPE	Polygonum persicaria	Spotted ladysthumb	N	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.5	6.0	1.9	3.7	ND
SCAM	Schoenoplectus americanus	American bulrush, threesquare bulrush	Y	0.0	0.0	0.0	0.0	0.1	0.4	6.3	12.5	0.0	0.0	0.0	0.0	0.0	0.0	ND
SISU	Sium suave	Hemlock waterparsnip	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.8	ND
BG		bare ground		64.4	10.8	53.1	11.3	48.1	29.4	2.8	4.9	34.4	14.7	36.9	16.0	13.1	7.0	ND
CALY-D	dead Carex lyngbyei	dead Lyngby sedge		0.0	0.0	0.0	0.0	0.0	0.0	25.0	13.5	0.0	0.0	0.0	0.0	0.0	0.0	ND
DETRITUS		detritus		8.1	4.6	3.1	3.7	1.9	2.6	0.0	0.0	20.6	12.7	1.3	2.3	8.8	8.3	ND
DW		drift wrack		0.0	0.0	0.0	0.0	0.0	0.0	1.3	2.5	0.0	0.0	0.0	0.0	0.0	0.0	ND
FGA		filamentous green algae		1.3	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ND
LITTER		litter		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.5	0.0	0.0	0.0	0.0	ND
SMH		small mixed herbs		0.8	0.5	0.0	0.0	0.0	0.0	0.0	0.0	1.9	2.0	0.0	0.0	0.0	0.0	ND
UID		unidentified species		0.1	0.4	0.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ND

Table C3. Monthly average percent cover at the study plots CALY5 and CALY6. Native status designations: M = mixed, N= no, not native, Y=yes, native.

				CALY5							CALY6							
				April		May		June		August	April		May		June		August	
Species Code	Scientific Name	Common Name	Native	Avg	SD	Avg	SD	Avg	SD		Avg	SD	Avg	SD	Avg	SD	Avg	SD
ALTR	Alisma triviale	northern water plaintain	Y	0.0	0.0	1.4	3.5	0.9	1.7	ND	0.0	0.0	0.0	0.0	0.1	0.4	1.3	2.5
AREG	Argentina egedii	Pacific silverweed	Y	0.5	0.5	0.0	0.0	0.0	0.0	ND	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BICE	Bidens cernua	Nodding beggars-ticks	Y	0.0	0.0	0.0	0.0	0.0	0.0	ND	0.0	0.0	0.0	0.0	0.0	0.0	3.0	4.7
CAHE	Callitriche heterophylla	Water starwort; Twoheaded water starwort	Y	0.0	0.0	3.3	5.9	0.8	1.8	ND	3.5	2.1	18.1	7.5	16.9	10.0	1.8	2.2
CAHE2	Callitriche hermaphroditica	northern water-starwort	Y	0.0	0.0	0.0	0.0	0.0	0.0	ND	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.5
CALY	Carex lyngbyei	Lyngby sedge	Y	33.1	10.0	36.3	9.9	66.3	10.3	ND	20.6	8.6	23.1	10.7	46.9	8.0	81.3	18.9
DECE	Deschampsia cespitosa	Tufted hairgrass	Y	1.3	2.3	0.0	0.0	0.0	0.0	ND	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ELPA	Eleocharis palustris	Common spikerush	Y	0.1	0.4	0.1	0.4	1.3	2.3	ND	0.1	0.4	2.6	3.7	0.9	1.7	1.3	2.5
EPCI	Epilobium ciliatum	Willow herb	Y	0.3	0.5	0.0	0.0	0.0	0.0	ND	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
JUOX	Juncus oxymeris	Pointed rush	Y	2.3	3.5	0.1	0.4	0.0	0.0	ND	0.0	0.0	0.0	0.0	0.0	0.0	3.8	7.5
LEOR	Leersia oryzoides	Rice cutgrass	Y	0.0	0.0	0.0	0.0	0.0	0.0	ND	0.0	0.0	0.0	0.0	0.0	0.0	2.8	2.6
LIOC	Lilaeopsis occidentalis	Western lilaeopsis	Y	0.0	0.0	0.0	0.0	0.0	0.0	ND	0.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0
LYSA	Lythrum salicaria	Purple loosestrife	N	0.0	0.0	3.1	4.6	0.0	0.0	ND	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MIGU	Mimulus guttatus	Yellow monkeyflower	Y	0.6	0.5	0.0	0.0	0.6	1.8	ND	0.6	0.5	0.0	0.0	0.0	0.0	2.0	2.0
MYSP	Myosotis laxa, M. scorpioides	Small forget-me-not, Common forget-me-not	M	0.0	0.0	0.6	1.8	0.0	0.0	ND	0.0	0.0	1.3	2.3	0.0	0.0	0.0	0.0
OESA	Oenanthe sarmentosa	Water parsley	Y	0.0	0.0	3.4	2.3	0.5	0.5	ND	0.3	0.5	0.0	0.0	0.3	0.5	0.0	0.0
PHAR	Phalaris arundinacea	Reed canary grass	N	0.0	0.0	0.0	0.0	0.0	0.0	ND	0.4	0.5	0.0	0.0	3.9	3.4	2.5	5.0
PLDI	Platanthera dilatata	white bog orchid	Y	0.1	0.4	0.0	0.0	0.0	0.0	ND	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
POHY	Polygonum hydropiper, P. hydropiperoides	Waterpepper, mild waterpepper, swamp smartweed	M	0.0	0.0	0.0	0.0	2.9	3.5	ND	0.0	0.0	0.0	0.0	8.8	4.4	0.5	0.6
POPE	Polygonum persicaria	Spotted ladysthumb	N	0.0	0.0	0.0	0.0	0.0	0.0	ND	0.0	0.0	14.4	9.8	0.1	0.4	0.0	0.0
SALA	Sagittaria latifolia	Wapato	Y	0.0	0.0	0.0	0.0	0.0	0.0	ND	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.5
SCTA	Schoenoplectus tabernaemontani	Softstem bulrush, tule	Y	0.4	0.5	0.0	0.0	1.3	3.5	ND	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SISU	Sium suave	Hemlock waterparsnip	Y	0.5	0.5	2.6	2.6	3.1	2.6	ND	0.0	0.0	0.1	0.4	5.6	3.2	0.3	0.5
TYSP	Typha angustifolia, T. latifolia	Narrowleaf cattail, common cattail	N	1.0	1.7	2.6	3.7	3.1	2.6	ND	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BG		bare ground		4.4	8.6	4.4	5.0	0.0	0.0	ND	63.1	8.8	40.0	17.3	12.5	9.6	10.3	10.5
CALY-D	dead Carex lyngbyei	dead Lyngby sedge		1.5	2.2	0.0	0.0	0.0	0.0	ND	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

				CALY5							CALY6							
				April		May		June		August	April		May		June		August	
Species Code	Scientific Name	Common Name	Native	Avg	SD	Avg	SD	Avg	SD		Avg	SD	Avg	SD	Avg	SD	Avg	SD
DETRITUS		detritus		48.1	12.2	42.5	10.7	20.0	8.9	ND	11.3	3.5	0.6	1.8	4.4	8.2	0.0	0.0
DW		drift wrack		0.1	0.4	0.0	0.0	0.0	0.0	ND	0.0	0.0	0.0	0.0	0.6	1.8	0.0	0.0
LITTER		litter		1.3	2.3	0.0	0.0	0.0	0.0	ND	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.5
SD		standing dead		3.3	2.4	0.3	0.5	0.0	0.0	ND	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SMH		small mixed herbs		5.3	3.4	0.0	0.0	0.0	0.0	ND	2.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0
UID		unidentified species		0.0	0.0	0.8	1.8	0.1	0.4	ND	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table C4. Monthly average percent cover at the study plots PHAR1 and PHAR2. Native status designations: M = mixed, N= no, not native, Y=yes, native.

				PHAR1								PHAR2						
				April		May		June		August		April		May		June		August
Species Code	Scientific Name	Common Name	Native	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	
ALTR	Alisma triviale	northern water plaintain	Y	0.0	0.0	0.3	0.5	0.1	0.4	1.5	2.4	0.0	0.0	0.1	0.4	0.0	0.0	ND
AREG	Argentina egedii	Pacific silverweed	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.5	0.0	0.0	0.0	0.0	ND
BICE	Bidens cernua	Nodding beggars-ticks	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	ND
CAHE	Callitriche heterophylla	Water starwort; Twoheaded water starwort	Y	0.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.5	ND
CALY	Carex lyngbyei	Lyngby sedge	Y	3.8	6.9	5.6	7.8	6.3	6.9	20.0	23.5	0.0	0.0	0.0	0.0	0.0	0.0	ND
ELPA	Eleocharis palustris	Common spikerush	Y	0.0	0.0	2.6	3.7	5.6	3.2	0.5	0.6	0.0	0.0	0.0	0.0	0.0	0.0	ND
EPCI	Epilobium ciliatum	Willow herb	Y	0.0	0.0	0.0	0.0	0.0	0.0	1.3	2.5	0.0	0.0	0.0	0.0	0.0	0.0	ND
EQPA	Equisetum palustre	marsh horsetail	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.6	1.8	0.0	0.0	ND
IRPS	Iris pseudacorus	Yellow iris	N	1.0	1.7	1.3	3.5	0.3	0.5	1.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	ND
LEOR	Leersia oryzoides	Rice cutgrass	Y	0.0	0.0	0.0	0.0	0.0	0.0	1.8	2.2	0.0	0.0	0.0	0.0	0.0	0.0	ND
LYSA	Lythrum salicaria	Purple loosestrife	N	0.0	0.0	0.0	0.0	0.6	1.8	0.0	0.0	0.0	0.0	0.6	1.8	0.0	0.0	ND
MIGU	Mimulus guttatus	Yellow monkeyflower	Y	0.0	0.0	0.1	0.4	0.0	0.0	0.3	0.5	0.1	0.4	0.0	0.0	1.5	2.2	ND
MYSP	Myosotis laxa, M. scorpioides	Small forget-me-not, Common forget-me-not	M	0.8	1.8	0.0	0.0	0.0	0.0	5.0	10.0	0.0	0.0	0.8	1.8	0.0	0.0	ND
OESA	Oenanthe sarmentosa	Water parsley	Y	0.0	0.0	0.1	0.4	0.1	0.4	0.0	0.0	0.0	0.0	0.9	1.7	1.3	1.6	ND
PHAR	Phalaris arundinacea	Reed canary grass	N	54.4	30.8	33.1	16.9	28.1	10.3	55.0	21.6	56.9	23.4	33.8	16.2	24.4	5.6	ND
POHY	Polygonum hydropiper, P. hydropiperoides	Waterpepper, mild waterpepper, swamp smartweed	M	0.0	0.0	0.0	0.0	0.1	0.4	0.5	0.6	0.0	0.0	0.0	0.0	3.3	3.6	ND
POPE	Polygonum persicaria	Spotted ladysthumb	N	0.3	0.5	0.1	0.4	0.6	1.8	0.0	0.0	0.0	0.0	2.5	5.3	0.0	0.0	ND
SALA	Sagittaria latifolia	Wapato	Y	0.0	0.0	0.0	0.0	5.6	3.2	17.5	20.2	0.0	0.0	0.0	0.0	0.0	0.0	ND
SASP-SAP	Salix spp. saplings	Willow saplings	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	3.7	6.3	7.9	1.3	2.3	ND
SCTA	Schoenoplectus tabernaemontani	Softstem bulrush, tule	Y	0.0	0.0	0.6	1.8	0.8	1.8	0.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	ND
SISU	Sium suave	Hemlock waterparsnip	Y	0.1	0.4	0.8	1.8	0.3	0.5	0.0	0.0	0.3	0.5	1.3	3.5	1.3	2.3	ND
SYSU	Symphyotrichum subspicatum	Douglas aster	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	1.8	0.0	0.0	0.0	0.0	ND
BG		bare ground		8.1	14.6	16.3	30.2	0.0	0.0	16.3	9.5	12.5	9.6	41.9	24.0	27.5	18.5	ND
CALY-D	dead Carex lyngbyei	dead Lyngby sedge		0.8	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ND
DETRITUS		detritus		14.4	19.4	36.9	24.8	52.5	13.1	3.8	2.5	25.0	24.9	10.6	14.5	39.4	18.4	ND
DW		drift wrack		1.3	2.3	3.9	7.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ND
LITTER		litter		0.8	1.8	0.0	0.0	0.1	0.4	0.0	0.0	5.5	5.5	0.1	0.4	0.8	1.8	ND
LWD		large woody debris		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	3.5	0.0	0.0	ND
MOSS		moss		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.8	ND

PHAR-D	dead Phalaris arundinacea	dead Reed canary grass	23.8	20.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ND
SD		standing dead	0.0	0.0	2.5	7.1	0.0	0.0	0.0	0.0	3.0	2.1	0.0	0.0	0.0	0.0	ND
SMH		small mixed herbs	0.3	0.5	0.1	0.4	0.0	0.0	0.0	0.0	1.5	1.4	0.0	0.0	0.0	0.0	ND
UID		unidentified species	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.0	0.0	0.0	0.0	ND

Table C5. Monthly average percent cover at the study plots PHAR3 and PHAR4. Native status designations: M = mixed, N= no, not native, Y=yes, native.

				PHAR3								PHAR4						
				April		May		June		August		April		May		June		August
Species Code	Scientific Name	Common Name	Native	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	
ALTR	Alisma triviale	northern water plaintain	Y	0.1	0.3	0.0	0.0	0.3	0.5	1.5	2.4	0.0	0.0	0.0	0.0	0.0	0.0	ND
AREG	Argentina egedii ssp. Egedii	Pacific silverweed	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.5	0.1	0.4	0.0	0.0	0.0	0.0	ND
CAHE	Callitriche heterophylla	Water starwort; Twoheaded water starwort	Y	0.2	0.4	0.1	0.3	0.5	0.5	1.8	2.2	0.0	0.0	0.0	0.0	0.0	0.0	ND
CAHE2	Callitriche hermaphroditica	northern water-starwort	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	ND
CALY	Carex lyngbyei	Lyngby sedge	Y	2.0	2.6	4.1	6.1	7.1	6.6	3.8	7.5	1.5	2.2	3.1	5.9	6.3	14.1	ND
ELPA	Eleocharis palustris	Common spikerush	Y	0.4	0.5	1.2	2.0	2.7	3.4	3.8	4.8	0.1	0.4	0.0	0.0	0.1	0.4	ND
EPCI	Epilobium ciliatum	Willow herb	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	1.7	0.0	0.0	ND
IRPS	Iris pseudacorus	Yellow iris	N	1.5	4.7	1.0	3.2	2.5	4.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ND
JUOX	Juncus oxymeris	Pointed rush	Y	0.0	0.0	3.6	5.7	0.0	0.0	0.0	0.0	0.0	0.0	0.8	1.8	0.0	0.0	ND
LEOR	Leersia oryzoides	Rice cutgrass	Y	0.0	0.0	0.0	0.0	0.0	0.0	1.5	2.4	0.0	0.0	0.0	0.0	0.0	0.0	ND
LIOC	Lilaeopsis occidentalis	Western lilaeopsis	Y	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ND
LYAM2	Lycopus americanus	American water horehound	Y	0.0	0.0	0.0	0.0	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ND
LYSA	Lythrum salicaria	Purple loosestrife	N	0.0	0.0	0.0	0.0	0.5	1.6	2.5	2.9	0.0	0.0	0.0	0.0	0.0	0.0	ND
MESP	Mentha spp.	Mint (field mint, spearmint)	M	0.5	0.5	0.7	1.6	2.5	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ND
MIGU	Mimulus guttatus	Yellow monkeyflower	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.6	0.0	0.0	0.0	0.0	0.0	0.0	ND
MYSC	Myosotis scorpioides	Common forget-me-not	N	0.0	0.0	0.0	0.0	0.0	0.0	4.0	7.3	0.0	0.0	0.0	0.0	0.0	0.0	ND
MYSP	Myosotis laxa, M. scorpioides	Small forget-me-not, Common forget-me-not	M	0.5	0.5	0.9	0.3	1.3	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ND
OESA	Oenanthe sarmentosa	Water parsley	Y	0.5	0.5	0.4	0.5	0.8	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	ND
PHAR	Phalaris arundinacea	Reed canary grass	N	44.5	20.3	25.0	12.5	26.5	10.3	75.0	17.8	70.6	10.2	51.3	26.8	38.1	18.3	ND
POHY	Polygonum hydropiper, P. hydropiperoides	Waterpepper, mild waterpepper, swamp smartweed	M	0.0	0.0	0.0	0.0	3.5	4.5	0.5	0.6	0.0	0.0	0.6	1.8	1.5	2.2	ND
POPE	Polygonum persicaria	Spotted ladysthumb	N	0.0	0.0	0.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0	1.4	3.5	0.1	0.4	ND
SALA	Sagittaria latifolia	Wapato	Y	0.0	0.0	0.0	0.0	1.0	3.2	6.5	7.2	0.0	0.0	0.0	0.0	0.0	0.0	ND
SASP-SAP	Salix spp.	Willow saplings	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	2.1	0.0	0.0	0.0	0.0	ND
SISU	Sium suave	Hemlock waterparsnip	Y	0.1	0.3	0.8	1.5	0.7	1.6	2.8	2.6	0.0	0.0	0.1	0.4	0.1	0.4	ND
TYAN	Typha angustifolia	Narrowleaf cattail	N	0.0	0.0	0.0	0.0	0.0	0.0	1.3	2.5	0.0	0.0	0.0	0.0	0.0	0.0	ND
BG		bare ground		9.0	9.4	0.5	1.6	0.0	0.0	1.8	2.2	18.8	8.3	40.0	18.9	31.9	14.4	ND
DETRITUS		detritus		19.0	16.3	52.0	16.4	51.5	19.7	6.3	2.5	2.0	3.7	1.3	2.3	22.5	13.9	ND
DW		drift wrack		12.0	14.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ND
LITTER		litter		1.2	2.0	0.0	0.0	0.6	1.6	0.0	0.0	0.6	1.8	0.0	0.0	0.0	0.0	ND
LWD		large woody debris		1.0	2.1	1.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ND
MOSS		moss		0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ND
PHAR-D	dead Phalaris arundinacea	dead Reed canary grass		16.0	11.7	0.0	0.0	0.0	0.0	0.0	0.0	5.3	3.4	0.0	0.0	0.0	0.0	ND
SD		standing dead		0.0	0.0	6.5	4.1	0.0	0.0	0.0	0.0	0.1	0.4	0.0	0.0	0.0	0.0	ND
SMH		small mixed herbs		0.5	0.5	0.6	1.6	0.0	0.0	0.0	0.0	0.1	0.4	0.0	0.0	0.0	0.0	ND
UID		unidentified species		0.2	0.4	0.2	0.4	0.0	0.0	0.5	0.6	0.0	0.0	0.0	0.0	0.0	0.0	ND

Table C6. Monthly average percent cover at the study plots PHAR3 and PHAR4. Native status designations: M = mixed, N= no, not native, Y=yes, native.

				CALY5							CALY6							
			Native	April		May		June		August	April		May		June		August	
Species Code	Scientific Name	Common Name		Avg	SD	Avg	SD	Avg	SD		Avg	SD	Avg	SD	Avg	SD	Avg	SD
AGST	Agrostis stolonifera L.	creeping bentgrass	N	0.6	1.6	0.0	0.0	0.0	0.0	ND	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ALTR	Alisma triviale	northern water plaintain	Y	0.4	0.5	0.5	1.6	1.7	2.3	ND	0.3	0.5	0.1	0.4	0.8	1.8	1.5	2.4
AREG	Argentina egedii ssp. Egedii	Pacific silverweed	Y	0.9	0.3	0.0	0.0	0.0	0.0	ND	0.3	0.5	0.1	0.4	0.0	0.0	0.3	0.5
BICE	Bidens cernua	Nodding beggars-ticks	Y	0.0	0.0	0.0	0.0	0.0	0.0	ND	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.5
CAHE	Callitriche heterophylla	Water starwort; Twoheaded water starwort	Y	0.3	0.5	0.0	0.0	0.2	0.4	ND	0.1	0.4	0.6	1.8	1.3	2.3	0.3	0.5
CALY	Carex lyngbyei	Lyngby sedge	Y	4.7	7.1	6.6	7.0	11.6	8.4	ND	0.6	1.8	0.0	0.0	0.0	0.0	0.0	0.0
CAPA	Caltha palustris	Yellow marsh marigold	Y	0.0	0.0	0.0	0.0	0.1	0.3	ND	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ELPA	Eleocharis palustris	Common spikerush	Y	0.6	0.5	0.6	1.6	0.7	1.6	ND	0.0	0.0	1.5	2.2	2.0	3.7	0.5	0.6
EPCI	Epilobium ciliatum	Willow herb	Y	0.0	0.0	0.0	0.0	0.0	0.0	ND	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.5
JUOX	Juncus oxymeris	Pointed rush	Y	0.0	0.0	2.7	3.4	0.6	1.6	ND	0.0	0.0	0.0	0.0	0.6	1.8	0.0	0.0
LYSA	Lythrum salicaria	Purple loosestrife	N	0.1	0.3	0.0	0.0	0.0	0.0	ND	0.0	0.0	0.0	0.0	1.9	5.3	0.0	0.0
MIGU	Mimulus guttatus	Yellow monkeyflower	Y	0.5	0.5	0.1	0.3	0.1	0.3	ND	0.1	0.4	0.1	0.4	0.0	0.0	0.0	0.0
MYSP	Myosotis laxa, M. scorpioides	Small forget-me-not, Common forget-me-not	M	0.0	0.0	0.6	1.6	0.0	0.0	ND	0.3	0.5	0.1	0.4	0.0	0.0	0.0	0.0
OESA	Oenanthe sarmentosa	Water parsley	Y	0.0	0.0	1.7	2.3	1.3	2.0	ND	0.0	0.0	0.6	1.8	0.1	0.4	0.0	0.0
PHAR	Phalaris arundinacea	Reed canary grass	N	38.5	15.8	26.0	9.1	27.0	9.2	ND	52.5	10.7	18.8	4.4	31.3	14.8	88.8	10.3
POHY	Polygonum hydropiper, P. hydropiperoides	Waterpepper, mild waterpepper, swamp smartweed	M	0.0	0.0	0.0	0.0	1.0	2.1	ND	0.0	0.0	0.0	0.0	1.0	1.7	1.5	2.4
POPE	Polygonum persicaria	Spotted ladysthumb	N	0.0	0.0	0.0	0.0	0.0	0.0	ND	0.1	0.4	0.0	0.0	0.0	0.0	1.3	2.5
SALA	Sagittaria latifolia	Wapato	Y	0.0	0.0	0.0	0.0	0.5	1.6	ND	0.0	0.0	0.0	0.0	3.4	2.3	11.3	7.5
SCTA	Schoenoplectus tabernaemontani	Softstem bulrush, tule	Y	0.6	1.6	0.0	0.0	2.0	3.5	ND	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SISU	Sium suave	Hemlock waterparsnip	Y	1.0	1.5	2.5	2.6	2.2	2.4	ND	0.0	0.0	0.0	0.0	0.1	0.4	1.3	2.5
SYSU	Symphyotrichum subspicatum	Douglas aster	Y	0.0	0.0	0.0	0.0	0.6	1.6	ND	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TYSP	Typha angustifolia, T. latifolia	Narrowleaf cattail, common cattail	N	0.0	0.0	0.0	0.0	0.1	0.3	ND	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BG		bare ground		12.0	11.6	54.0	13.1	7.5	10.3	ND	11.3	10.9	0.0	0.0	6.3	10.6	1.5	2.4
DETRITUS		detritus		39.5	18.5	4.5	4.4	43.5	13.6	ND	11.9	15.1	69.4	13.5	46.3	13.6	0.0	0.0
DW		drift wrack		2.2	4.8	0.5	1.6	0.0	0.0	ND	0.0	0.0	0.0	0.0	0.0	0.0	1.5	2.4
LITTER		litter		0.7	1.6	0.1	0.3	0.5	1.6	ND	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LWD		large woody debris		0.0	0.0	0.0	0.0	0.0	0.0	ND	1.3	2.3	6.9	14.4	5.0	10.4	2.5	2.9
PHAR-D	dead Phalaris	dead Reed canary grass		2.2	2.4	0.0	0.0	0.0	0.0	ND	27.5	21.2	0.0	0.0	0.0	0.0	0.0	0.0

				CALY5							CALY6							
				April		May		June		August	April		May		June		August	
Species Code	Scientific Name	Common Name	Native	Avg	SD	Avg	SD	Avg	SD		Avg	SD	Avg	SD	Avg	SD	Avg	SD
	arundinacea																	
SD		standing dead		0.0	0.0	0.5	1.6	0.1	0.3	ND	0.0	0.0	1.3	3.5	1.3	3.5	0.0	0.0
SMH		small mixed herbs		1.3	1.3	0.6	1.6	0.1	0.3	ND	0.1	0.4	0.8	1.8	0.0	0.0	0.0	0.0
UID		unidentified species		0.0	0.0	0.1	0.3	0.2	0.4	ND	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table C7. Average percent cover for the area surrounding the CALY study plots as surveyed in August 2014. Native status designations: M = mixed, N= no, not native, Y=yes, native.

				CALY											
				CALY1		CALY2		CALY3		CALY4		CALY5		CALY6	
Species Code	Scientific Name	Common Name	Native	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
AGGI	Agrostis gigantea	redtop; black bentgrass	N	0.0	0.0	0.2	0.4	0.0	0.0	0.0	0.0	0.1	0.3	0.0	0.0
AGST	Agrostis stolonifera L.	creeping bentgrass		0.0	0.0	0.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ALTR	Alisma triviale	northern water plaintain	Y	0.2	0.4	0.1	0.3	0.2	0.4	0.4	0.5	2.2	3.2	0.1	0.3
AREG	Argentina egedii ssp. Egedii	Pacific silverweed	Y	0.0	0.0	3.3	4.8	0.0	0.0	0.0	0.0	0.4	0.5	0.0	0.0
BICE	Bidens cernua	Nodding beggars-ticks	Y	1.0	1.6	0.8	1.4	0.3	0.5	0.0	0.0	2.8	4.3	0.8	1.2
CAHE	Callitriche heterophylla	Water starwort; Twoheaded water starwort	Y	1.2	1.5	0.3	1.0	0.6	0.5	0.0	0.0	0.8	1.0	2.1	7.2
CAHE2	Callitriche hermaphroditica	northern water-starwort	Y	0.1	0.3	0.04	0.2	0.3	0.5	0.0	0.0	0.8	1.0	0.2	0.4
CALY	Carex lyngbyei	Lyngby sedge	Y	30.3	43.1	66.2	31.9	41.2	44.9	46.9	44.7	51.8	31.5	45.0	45.3
CAPA	Caltha palustris	Yellow marsh marigold	Y	0.0	0.0	3.2	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CEDE	Ceratophyllum demersum	Coontail	Y	0.3	0.4	0.04	0.2	0.04	0.2	0.0	0.0	0.0	0.0	0.03	0.2
DECE	Deschampsia cespitosa	Tufted hairgrass	Y	0.0	0.0	1.7	4.2	0.0	0.0	3.9	11.6	0.2	0.4	1.0	5.5
ELAC	Eleocharis acicularis	Needle spikerush	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.04	0.2	0.04	0.2	0.0	0.0
ELCA	Elodea canadensis	Canada waterweed	Y	3.2	10.2	0.1	0.3	0.04	0.2	0.0	0.0	0.6	2.0	1.0	3.7
ELPA	Eleocharis palustris	Common spikerush	Y	14.4	26.1	3.0	12.0	32.1	36.7	7.0	20.0	0.8	1.0	17.9	29.7
EPCI	Epilobium ciliatum	Willow herb	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.04	0.2	0.1	0.3	0.0	0.0
EQFL	Equisetum fluviatile	Water horsetail	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.0	0.0	0.0	0.0	0.0
EQPA	Equisetum palustre	marsh horsetail	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.0	0.0	0.0	0.0	0.0
GATR	Galium trifidum L. spp. columbianum	Pacific bedstraw	Y	0.0	0.0	0.2	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GLST	Glyceria striata	Fowl mannagrass	Y	0.0	0.0	0.04	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GRNE	Gratiola neglecta	American Hedge-hyssop	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.04	0.2	0.0	0.0
HYSC	Hypericum scouleri	Western St. John’s wort	Y	0.0	0.0	0.6	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IMSP	Impatiens capensis,Impatiens noli-tangere	western touch-me-not, common touch-me-not, jewelweed	Y	0.0	0.0	0.2	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IRPS	Iris pseudacorus	Yellow iris	N	0.0	0.0	0.6	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ISSP	Isoetes spp.	quillwort	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	1.8	0.0	0.0
JUOX	Juncus oxymeris	Pointed rush	Y	0.0	0.0	1.5	2.5	0.8	1.6	1.5	3.0	1.4	1.9	0.7	1.5
LAPA	Lathyrus palustris	Marsh peavine	Y	0.0	0.0	0.04	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LEOR	Leersia oryzoides	Rice cutgrass	Y	0.4	1.1	0.4	1.0	0.4	1.0	1.4	2.6	0.4	1.0	0.9	2.1
LIAQ	Limosella aquatica	Water mudwort	Y	0.3	0.5	0.1	0.3	0.7	1.0	0.0	0.0	0.2	0.4	0.2	0.4
LIOC	Lilaeopsis occidentalis	Western lilaeopsis	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.0	0.8	2.2	0.0	0.0
LISC	Lilaea scilloides	Flowering quillwort	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.04	0.2	0.0	0.0
LYAM	Lysichiton americanus	Skunk cabbage	Y	0.0	0.0	2.3	7.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

				CALY											
				CALY1		CALY2		CALY3		CALY4		CALY5		CALY6	
Species Code	**Scientific Name**	**Common Name**	**Native**	**Avg**	**SD**	**Avg**	**SD**	**Avg**	**SD**	**Avg**	**SD**	**Avg**	**SD**	**Avg**	**SD**
LYSA	Lythrum salicaria	Purple loosestrife	N	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	4.7	0.0	0.0
MEAR	Mentha arvensis	wild mint	Y	0.0	0.0	0.9	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MIGU	Mimulus guttatus	Yellow monkeyflower	Y	0.1	0.3	1.0	1.6	0.1	0.3	1.4	2.1	1.0	1.6	0.4	0.5
MYLA	Myosotis laxa	Small forget-me-not	Y	0.0	0.0	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MYSC	Myosotis scorpioides	Common forget-me-not	N	0.0	0.0	0.2	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MYSP	Myosotis laxa, M. scorpioides	Small forget-me-not, Common forget-me-not	M	0.0	0.0	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MYSP2	Myriophyllum spp.	Milfoil	M	0.04	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OESA	Oenanthe sarmentosa	Water parsley	Y	0.0	0.0	1.6	3.3	0.0	0.0	0.04	0.2	0.4	0.5	0.03	0.2
PHAR	Phalaris arundinacea	Reed canary grass	N	0.3	1.0	4.0	16.1	0.2	1.0	19.3	35.8	4.6	13.4	8.5	25.0
POHY	Polygonum hydropiper, P. hydropiperoides	Waterpepper, mild waterpepper, swamp smartweed	M	1.3	2.9	0.4	0.5	0.1	0.3	0.4	0.5	1.2	1.5	0.5	1.0
POPE	Polygonum persicaria	Spotted ladysthumb	N	0.0	0.0	0.3	1.0	0.0	0.0	0.0	0.0	0.2	1.0	0.0	0.0
POPU	Potamogeton pusillus	Small pondweed	Y	0.3	0.4	0.0	0.0	0.2	0.4	0.0	0.0	0.0	0.0	1.1	5.5
PORI	Potamogeton richardsonii	Richardson's pondweed	Y	0.3	1.0	0.2	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.3
RUCR	Rumex crispus	Curly dock	N	0.0	0.0	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BG		Bare ground		40.6	37.4	8.5	13.1	26.4	33.0	15.1	23.6	13.0	10.4	23.0	27.1
DETRITUS		Detritus		0.0	0.0	0.2	1.0	0.0	0.0	0.04	0.2	0.3	1.0	0.0	0.0
DW		Drift wrack		0.4	2.0	2.2	5.4	1.3	5.0	0.5	1.4	0.6	3.0	0.2	0.9
FGA		Filamentous green algae		0.04	0.2	0.0	0.0	5.4	16.6	0.1	0.3	0.0	0.0	0.5	1.5
LITTER		Litter		0.0	0.0	0.04	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LWD		Large woody debris		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.0	0.7	3.7
MOSS		Moss		0.0	0.0	0.2	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PHAR-D	dead Phalaris arundinacea	dead Reed canary grass		0.0	0.0	0.04	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SASI-SAP	Salix sitchensis saplings	Sitka willow saplings		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.9
SASI-SD	standing dead Salix sitchensis	standing dead Sitka willow		0.0	0.0	1.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SD		Standing dead		0.0	0.0	0.0	0.0	0.0	0.0	0.04	0.2	0.0	0.0	0.0	0.0
SH		Shell hash		0.0	0.0	0.0	0.0	0.0	0.0	0.04	0.2	0.0	0.0	0.0	0.0
SMG		Small mixed grass		0.0	0.0	0.8	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SMH		Small mixed herbs		0.0	0.0	0.2	0.4	0.0	0.0	0.04	0.2	0.1	0.3	0.0	0.0
UID		unidentified species		0.0	0.0	0.9	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table C8. Average percent cover for the area surrounding the PHAR study plots as surveyed in August 2014. Native status designations: M = mixed, N= no, not native, Y=yes, native.

				PHAR											
				PHAR1		PHAR2		PHAR3		PHAR4		PHAR5		PHAR6	
Species Code	Scientific Name	Common Name	Native	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
AGST	Agrostis stolonifera L.	creeping bentgrass	N	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.0	0.0	0.0
ALTR	Alisma triviale	northern water plaintain	Y	0.5	1.1	0.7	1.3	0.4	1.2	0.3	0.4	2.5	2.5	0.8	1.6
AREG	Argentina egedii ssp. Egedii	Pacific silverweed	Y	0.0	0.0	0.5	2.7	0.2	0.9	0.0	0.0	0.1	0.3	0.0	0.0
BICE	Bidens cernua	Nodding beggars-ticks	Y	0.9	2.2	0.6	1.5	0.3	0.9	0.04	0.2	1.5	2.6	2.0	5.1
CAHE	Callitriche heterophylla	Water starwort; Twoheaded water starwort	Y	1.5	4.1	0.2	0.4	0.4	0.9	0.0	0.0	2.0	3.1	0.2	0.4
CAHE2	Callitriche hermaphroditica	northern water-starwort	Y	0.0	0.0	0.5	1.0	0.03	0.2	0.0	0.0	0.4	0.5	0.0	0.0
CALY	Carex lyngbyei	Lyngby sedge	Y	33.9	41.6	21.3	37.6	12.4	23.4	5.3	12.1	50.0	36.8	3.4	8.1
CEDE	Ceratophyllum demersum	Coontail	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	2.0	0.0	0.0
CIDO	Cicuta douglasii	Western water-hemlock	Y	0.0	0.0	0.2	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DECE	Deschampsia cespitosa	Tufted hairgrass	Y	0.0	0.0	0.2	0.9	0.2	0.9	0.1	0.3	0.0	0.0	0.0	0.0
ELAC	Eleocharis acicularis	Needle spikerush	Y	0.0	0.0	1.9	9.1	0.0	0.0	2.3	8.6	0.0	0.0	0.0	0.0
ELCA	Elodea canadensis	Canada waterweed	Y	3.4	10.5	0.0	0.0	0.0	0.0	2.1	10.2	3.1	10.8	0.2	1.0
ELNU	Elodea nuttallii	Nuttall's waterweed, western waterweed	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.0	0.0	0.0
ELPA	Eleocharis palustris	Common spikerush	Y	7.4	17.7	21.3	34.6	6.7	13.5	19.0	31.3	0.7	1.4	1.5	2.3
EPCI	Epilobium ciliatum	Willow herb	Y	0.4	1.4	0.0	0.0	0.1	0.3	0.0	0.0	0.3	1.0	0.04	0.2
EQFL	Equisetum fluviatile	Water horsetail	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.04	0.2
EQPA	Equisetum palustre	marsh horsetail	Y	0.0	0.0	0.03	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ERPH	Erigeron philadelphicus L.	Philidelphia fleabane	Y	0.0	0.0	0.0	0.0	0.2	0.9	0.0	0.0	0.0	0.0	0.0	0.0
GATR	Galium trifidum L. spp. columbianum	Pacific bedstraw	Y	0.0	0.0	0.0	0.0	0.2	0.9	0.0	0.0	0.0	0.0	0.0	0.0
GRNE	Gratiola neglecta	American Hedge-hyssop	Y	0.0	0.0	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IMNO	Impatiens noli-tangere	western touch-me-not	Y	0.0	0.0	0.0	0.0	0.5	2.5	0.0	0.0	0.0	0.0	0.0	0.0
IMSP	Impatiens capensis,Impatiens noli-tangere	western touch-me-not, common touch-me-not, jewelweed	Y	0.0	0.0	3.2	17.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IRPS	Iris pseudacorus	Yellow iris	N	0.04	0.2	0.0	0.0	0.4	1.2	0.0	0.0	0.0	0.0	0.2	1.0
ISSP	Isoetes spp.	quillwort	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.5	0.0	0.0
JUBU	Juncus bufonius	Toad rush	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.04	0.2	0.0	0.0
JUOX	Juncus oxymeris	Pointed rush	Y	0.04	0.2	0.7	2.7	1.0	2.1	1.5	4.0	0.9	1.6	0.04	0.2
LEOR	Leersia oryzoides	Rice cutgrass	Y	0.2	0.4	0.7	3.7	0.4	0.9	0.3	1.0	0.0	0.0	0.0	0.0
LIAQ	Limosella aquatica	Water mudwort	Y	0.0	0.0	0.7	1.5	0.1	0.4	0.0	0.0	0.3	0.4	0.0	0.0
LIOC	Lilaeopsis occidentalis	Western lilaeopsis	Y	0.0	0.0	0.4	1.0	0.1	0.3	0.1	0.3	0.5	2.0	0.0	0.0

				PHAR											
				PHAR1		PHAR2		PHAR3		PHAR4		PHAR5		PHAR6	
Species Code	**Scientific Name**	**Common Name**	**Native**	**Avg**	**SD**	**Avg**	**SD**	**Avg**	**SD**	**Avg**	**SD**	**Avg**	**SD**	**Avg**	**SD**
LOCO	Lotus corniculatus	Birdsfoot trefoil	N	0.0	0.0	0.0	0.0	0.3	1.7	0.0	0.0	0.0	0.0	0.0	0.0
LYSA	Lythrum salicaria	Purple loosestrife	N	0.3	1.0	1.3	7.3	0.6	2.6	0.4	1.4	1.3	6.1	0.04	0.2
MEAR	Mentha arvensis	wild mint	Y	0.0	0.0	0.03	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MEOF	Melissa officinalis	common balm; lemon balm	N	0.0	0.0	0.0	0.0	1.0	3.7	0.0	0.0	0.0	0.0	0.0	0.0
MESP3	Mentha spicata	spearmint	N	0.0	0.0	0.0	0.0	0.1	0.8	0.0	0.0	0.0	0.0	0.0	0.0
MIGU	Mimulus guttatus	Yellow monkeyflower	Y	0.1	0.3	0.2	0.4	0.3	0.9	0.5	2.0	0.4	1.1	0.1	0.3
MYLA	Myosotis laxa	Small forget-me-not	Y	0.8	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MYSC	Myosotis scorpioides	Common forget-me-not	N	0.04	0.2	0.2	0.9	2.1	5.9	0.0	0.0	0.0	0.0	0.0	0.0
MYSP2	Myriophyllum spp.	Milfoil	M	0.3	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OESA	Oenanthe sarmentosa	Water parsley	Y	0.0	0.0	0.1	0.3	0.1	0.4	0.04	0.2	0.3	1.0	0.1	0.3
PHAR	Phalaris arundinacea	Reed canary grass	N	26.8	38.3	33.3	43.1	37.9	40.3	59.2	43.2	24.8	36.8	27.2	39.6
POCR	Potamogeton crispus	Curly leaf pondweed	N	0.0	0.0	0.03	0.2	0.0	0.0	0.0	0.0	0.04	0.2	0.0	0.0
POHY	Polygonum hydropiper, P. hydropiperoides	Waterpepper, mild waterpepper, swamp smartweed	M	1.1	2.3	1.0	2.1	0.5	0.9	0.8	2.2	1.8	2.8	1.4	4.1
POPE	Polygonum persicaria	Spotted ladysthumb	N	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.0	0.1	0.3
POPU	Potamogeton pusillus	Small pondweed	Y	0.04	0.2	0.2	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PORI	Potamogeton richardsonii	Richardson's pondweed	Y	0.04	0.2	0.2	0.9	0.0	0.0	0.2	1.0	0.04	0.2	0.0	0.0
PRVU	Prunella vulgaris	Self heal	Y	0.0	0.0	0.0	0.0	0.03	0.2	0.0	0.0	0.0	0.0	0.0	0.0
ROSP	Rorippa calycina, R.curvisiliqua	Yellow cress	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.0	0.0
RUCR	Rumex crispus	Curly dock	N	0.0	0.0	0.03	0.2	0.03	0.2	0.0	0.0	0.0	0.0	0.0	0.0
SALA	Sagittaria latifolia	Wapato	Y	9.6	12.5	0.0	0.0	0.2	0.9	0.1	0.3	6.8	9.0	22.7	21.0
SASE	Salix sessilifolia Nutt.	Columbia River willow, river willow	Y	0.0	0.0	1.2	4.9	0.3	1.7	6.9	21.6	0.0	0.0	0.0	0.0
SASI	Salix sitchensis	Sitka willow	Y	0.2	1.0	0.0	0.0	5.0	18.3	0.0	0.0	0.0	0.0	0.0	0.0
SCAM	Schoenoplectus americanus	American bulrush, threesquare bulrush	Y	0.1	0.3	0.1	0.3	0.1	0.2	0.0	0.0	0.0	0.0	0.1	0.3
SCTA	Schoenoplectus tabernaemontani	Softstem bulrush, tule	Y	0.04	0.2	0.0	0.0	0.0	0.0	0.0	0.0	1.6	2.7	0.04	0.2
SISU	Sium suave	Hemlock waterparsnip	Y	0.04	0.2	1.9	4.0	0.5	1.2	0.1	0.3	2.0	2.4	1.2	3.2
SYEA	Symphyotrichum eatonii	Eaton's aster	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.0	0.0	0.0
SYSU	Symphyotrichum subspicatum	Douglas aster	Y	0.0	0.0	0.1	0.3	0.3	0.9	0.2	1.0	0.5	2.0	0.0	0.0
TYAN	Typha angustifolia	Narrowleaf cattail	N	0.0	0.0	0.2	0.9	0.03	0.2	0.0	0.0	3.1	2.8	0.0	0.0
VEAM	Veronica americana	American speedwell	Y	0.0	0.0	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BG		Bare ground		13.6	25.0	14.6	25.7	24.7	32.2	12.4	18.8	8.6	9.4	41.2	32.9
DETRITUS		Drift wrack		2.7	7.4	0.4	1.3	6.6	21.4	0.0	0.0	0.0	0.0	0.4	2.0

				PHAR											
				PHAR1		PHAR2		PHAR3		PHAR4		PHAR5		PHAR6	
Species Code	**Scientific Name**	**Common Name**	**Native**	**Avg**	**SD**	**Avg**	**SD**	**Avg**	**SD**	**Avg**	**SD**	**Avg**	**SD**	**Avg**	**SD**
DW		Large woody debris		1.0	5.1	0.0	0.0	0.4	1.9	0.0	0.0	0.0	0.0	0.0	0.0
FGA		Filamentous green algae		0.0	0.0	0.7	2.2	0.03	0.2	0.0	0.0	0.0	0.0	0.0	0.0
LITTER		Litter		0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.04	0.2	0.2	1.0
LWD		Shell hash		0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.4	0.0	0.0	0.0	0.0
MOSS		Moss		0.0	0.0	0.03	0.2	0.0	0.0	0.0	0.0	0.2	1.0	0.0	0.0
PHAR-D	dead Phalaris arundinacea	Small mixed herbs		0.0	0.0	0.03	0.2	0.0	0.0	0.0	0.0	0.2	1.0	0.0	0.0
SASI-SAP	Salix sitchensis saplings	Standing dead		0.04	0.2	0.03	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SASI-SD	standing dead Salix sitchensis	Detritus		0.0	0.0	0.0	0.0	0.0	0.0	0.04	0.2	0.0	0.0	0.0	0.0

Appendix D. Macroinvertebrate sampling design.

Table D.1. Invertebrate samples planned, collected in the field, and processed in the lab. The notes column describes why discrepancies occur between the number of samples planned, collected, and processed in some months.

Sample Type	Samples Planned	Samples Collected	Samples Processed	Notes
Fallout Traps	Total: 150 50 samples per month	Total: 146 April: 46 May: 50 June: 50	Total: 143 April: 43 May: 50 June: 50	In April: Traps swamped due to stormy weather were reset and attempted a second time with extra flotation. Four samples were swamped or overturned a second time, and could not be collected in the field. Three samples were accidentally not preserved after they were collected, and the sample contents decayed before they could be processed in the lab. All samples were collected, preserved, and processed normally from May and June.
Emergence Traps	Total: 150 50 samples per month	Total: 144 April: 46 May: 49 June: 49	Total: 144 April: 46 May: 59 June: 59	In April, stormy weather compromised four emergence traps, and samples could not be collected in the field. In both May and June, one trap was compromised at the PHAR2 site. All other samples were collected. All samples collected in the field were processed.
Benthic Cores	Total: 150 50 samples per month	Total: 150 April: 50 May: 50 June: 50	Total: 150 April: 50 May: 50 June: 50	All benthic cores were collected as per protocol in all three sampling months, and all samples were processed.

Appendix E. Macroinvertebrate ANOSIM results

Table E.1. ANOSIM results of A) fallout trap abundance, B) fallout trap biomass, C) emergence trap abundance, D) emergence trap biomass, E) benthic core abundance, and F) benthic core biomass.

A) Fallout Trap Abundance
Factor: Month
April
June
May

Global Test
Sample statistic (Global R): 0.647
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to Global R: 0

Pairwise Tests

Groups	R Statistic	Sig. Level %	Possible Permutations	Actual Permutations	No. >= Observed
April, June	0.833	0.1	1352078	999	0
April, May	0.581	0.1	1352078	999	0
June, May	0.56	0.1	1352078	999	0

Factor: Plant-Month
CALY-April
PHAR-April
CALY-June
PHAR-June
CALY-May
PHAR-May

Global Test
Sample statistic (Global R): 0.595
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to Global R: 0

Pairwise Tests

Groups	R Statistic	Sig. Level %	Possible Permutations	Actual Permutations	No. >= Observed
CALY-April, PHAR-April	0.248	1.5	462	462	7
CALY-April, CALY-June	0.985	0.2	462	462	1
CALY-April, PHAR-June	0.993	0.2	462	462	1
CALY-April, CALY-May	0.652	0.2	462	462	1
CALY-April, PHAR-May	0.846	0.2	462	462	1
PHAR-April, CALY-June	0.763	0.2	462	462	1
PHAR-April, PHAR-June	0.785	0.2	462	462	1
PHAR-April, CALY-May	0.63	0.2	462	462	1
PHAR-April, PHAR-May	0.513	0.2	462	462	1

CALY-June, PHAR-June	0.107	16.9	462	462	78
CALY-June, CALY-May	0.646	0.2	462	462	1
CALY-June, PHAR-May	0.583	0.4	462	462	2
PHAR-June, CALY-May	0.726	0.2	462	462	1
PHAR-June, PHAR-May	0.569	0.2	462	462	1
CALY-May, PHAR-May	0.056	27.7	462	462	128

B) Fallout Trap Biomass

Factor: Month
April
June
May

Global Test
Sample statistic (Global R): 0.535
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to Global R: 0

Pairwise Tests

Groups	R Statistic	Sig. Level %	Possible Permutations	Actual Permutations	No. >= Observed
April, June	0.662	0.1	1352078	999	0
April, May	0.444	0.1	1352078	999	0
June, May	0.514	0.1	1352078	999	0

Factor: Plant-Month
CALY-April
PHAR-April
CALY-June
PHAR-June
CALY-May
PHAR-May

Global Test
Sample statistic (Global R): 0.474
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to Global R: 0

Pairwise Tests

Groups	R Statistic	Sig. Level %	Possible Permutations	Actual Permutations	No. >= Observed
CALY-April, PHAR-April	0.031	31.6	462	462	146
CALY-April, CALY-June	0.715	0.2	462	462	1
CALY-April, PHAR-June	0.757	0.2	462	462	1
CALY-April, CALY-May	0.363	0.9	462	462	4
CALY-April, PHAR-May	0.706	0.2	462	462	1
PHAR-April, CALY-June	0.639	0.2	462	462	1
PHAR-April, PHAR-June	0.67	0.2	462	462	1
PHAR-April, CALY-May	0.4	0.2	462	462	1

PHAR-April, PHAR-May	0.585	0.2	462	462	1
CALY-June, PHAR-June	0.019	36.4	462	462	168
CALY-June, CALY-May	0.596	0.2	462	462	1
CALY-June, PHAR-May	0.463	0.9	462	462	4
PHAR-June, CALY-May	0.674	0.2	462	462	1
PHAR-June, PHAR-May	0.474	0.4	462	462	2
CALY-May, PHAR-May	0.285	3.7	462	462	17

C) Emergence Trap Abundance

Factor: Month
April
June
May

Global Test
Sample statistic (Global R): 0.628
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to Global R: 0

Pairwise Tests

Groups	R Statistic	Sig. Level %	Possible Permutations	Actual Permutations	No. >= Observed
April, June	0.858	0.1	1352078	999	0
April, May	0.599	0.1	1352078	999	0
June, May	0.512	0.1	1352078	999	0

Factor: Plant-Month
CALY-April
PHAR-April
CALY-June
PHAR-June
CALY-May
PHAR-May

Global Test
Sample statistic (Global R): 0.625
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to Global R: 0

Pairwise Tests

Groups	R Statistic	Sig. Level %	Possible Permutations	Actual Permutations	No. >= Observed
CALY-April, PHAR-April	0.211	6.9	462	462	32
CALY-April, CALY-June	0.952	0.2	462	462	1
CALY-April, PHAR-June	0.985	0.2	462	462	1
CALY-April, CALY-May	0.759	0.2	462	462	1
CALY-April, PHAR-May	0.883	0.2	462	462	1
PHAR-April, CALY-June	0.787	0.2	462	462	1
PHAR-April, PHAR-June	0.893	0.2	462	462	1

PHAR-April, CALY-May	0.583	0.2	462	462	1
PHAR-April, PHAR-May	0.53	0.4	462	462	2
CALY-June, PHAR-June	0.53	0.6	462	462	3
CALY-June, CALY-May	0.643	0.2	462	462	1
CALY-June, PHAR-May	0.524	0.2	462	462	1
PHAR-June, CALY-May	0.844	0.2	462	462	1
PHAR-June, PHAR-May	0.685	0.2	462	462	1
CALY-May, PHAR-May	0.117	13	462	462	60

D) Emergence Trap Biomass

Factor: Month
April
June
May

Global Test
Sample statistic (Global R): 0.589
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to Global R: 0

Pairwise Tests

Groups	R Statistic	Sig. Level %	Possible Permutations	Actual Permutations	No. >= Observed
April, June	0.858	0.1	1352078	999	0
April, May	0.592	0.1	1352078	999	0
June, May	0.281	0.1	1352078	999	0

Factor: Plant-Month
CALY-April
PHAR-April
CALY-June
PHAR-June
CALY-May
PHAR-May

Global Test
Sample statistic (Global R): 0.557
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to Global R: 0

Pairwise Tests

Groups	R Statistic	Sig. Level %	Possible Permutations	Actual Permutations	No. >= Observed
CALY-April, PHAR-April	0.1	11.3	462	462	52
CALY-April, CALY-June	0.883	0.2	462	462	1
CALY-April, PHAR-June	0.976	0.2	462	462	1
CALY-April, CALY-May	0.639	0.9	462	462	4
CALY-April, PHAR-May	0.876	0.2	462	462	1
PHAR-April, CALY-June	0.715	0.2	462	462	1

PHAR-April, PHAR-June	0.856	0.2	462	462	1
PHAR-April, CALY-May	0.454	0.6	462	462	3
PHAR-April, PHAR-May	0.667	0.2	462	462	1
CALY-June, PHAR-June	0.159	8	462	462	37
CALY-June, CALY-May	0.37	0.6	462	462	3
CALY-June, PHAR-May	0.133	13.6	462	462	63
PHAR-June, CALY-May	0.728	0.2	462	462	1
PHAR-June, PHAR-May	0.448	0.2	462	462	1
CALY-May, PHAR-May	0.406	1.1	462	462	5

E) Benthic Core Abundance

Factor: Month
April
June
May

Global Test
Sample statistic (Global R): 0.019
Significance level of sample statistic: 26.5%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to Global R: 264

Pairwise Tests

Groups	R Statistic	Sig. Level %	Possible Permutations	Actual Permutations	No. >= Observed
April, June	0.024	29	1352078	999	289
April, May	0.047	17	1352078	999	169
June, May	-0.011	53.9	1352078	999	538

Factor: Plant-Month
CALY-April
PHAR-April
CALY-June
PHAR-June
CALY-May
PHAR-May

Global Test
Sample statistic (Global R): -0.01
Significance level of sample statistic: 54.2%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to Global R: 541

Pairwise Tests

Groups	R Statistic	Sig. Level %	Possible Permutations	Actual Permutations	No. >= Observed
CALY-April, PHAR-April	-0.111	88.3	462	462	408
CALY-April, CALY-June	-0.043	60.6	462	462	280
CALY-April, PHAR-June	0.022	34.2	462	462	158
CALY-April, CALY-May	-0.052	62.8	462	462	290
CALY-April, PHAR-May	0.076	17.1	462	462	79

PHAR-April, CALY-June	-0.067	72.1	462	462	333
PHAR-April, PHAR-June	-0.022	53.7	462	462	248
PHAR-April, CALY-May	-0.046	58.2	462	462	269
PHAR-April, PHAR-May	0.13	11.9	462	462	55
CALY-June, PHAR-June	-0.057	73.2	462	462	338
CALY-June, CALY-May	-0.169	93.1	462	462	430
CALY-June, PHAR-May	0.076	21.6	462	462	100
PHAR-June, CALY-May	0.002	43.5	462	462	201
PHAR-June, PHAR-May	-0.03	56.9	462	462	263
CALY-May, PHAR-May	0.094	20.1	462	462	93

F) Benthic Core Biomass

Factor: Month
April
June
May

Global Test
Sample statistic (Global R): 0.088
Significance level of sample statistic: 2.6%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to Global R: 25

Pairwise Tests

Groups	R Statistic	Sig. Level %	Possible Permutations	Actual Permutations	No. >= Observed
April, June	0.065	11.1	1352078	999	110
April, May	0.132	3.5	1352078	999	34
June, May	0.071	9.1	1352078	999	90

Factor: Plant-Month
CALY-April
PHAR-April
CALY-June
PHAR-June
CALY-May
PHAR-May

Global Test
Sample statistic (Global R): 0.088
Significance level of sample statistic: 4%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to Global R: 39

Pairwise Tests

Groups	R Statistic	Sig. Level %	Possible Permutations	Actual Permutations	No. >= Observed
CALY-April, PHAR-April	0.215	6.7	462	462	31
CALY-April, CALY-June	0.185	6.3	462	462	29
CALY-April, PHAR-June	-0.013	53	462	462	245
CALY-April, CALY-May	-0.011	50	462	462	231

CALY-April, PHAR-May	0.076	22.1	462	462	102
PHAR-April, CALY-June	0.172	10.8	462	462	50
PHAR-April, PHAR-June	0.007	40	462	462	185
PHAR-April, CALY-May	0.283	3.5	462	462	16
PHAR-April, PHAR-May	0.239	4.1	462	462	19
CALY-June, PHAR-June	-0.041	63.9	462	462	295
CALY-June, CALY-May	0.009	44.4	462	462	205
CALY-June, PHAR-May	0.148	12.8	462	462	59
PHAR-June, CALY-May	0.085	18.2	462	462	84
PHAR-June, PHAR-May	-0.02	58.9	462	462	272
CALY-May, PHAR-May	-0.015	53.5	462	462	247